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ITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Washington, D.C.

LABORATORY INVESTIGATIONS on BED-LOAD TRANSPORTATION AND BED ROUGHNESS

A Compilation of Published and Unpublished Data
by
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Hydraulic Engineer

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Sedimentation Section
Office of Research

SCS-TP-50
March, 1943

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Prepared under the direction of
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FOREWORD

As this global war progresses, it becomes more and more evident that production of food and other crops is vital to Victory and to the Peace that is to follow. All available land of high fertility should be used for crop production and, through good farm management and soil and water conservation, made to produce as intensively as possible. The amount of this class of land is large, but in view of the expected need for crops, it is not large enough. Quality of land is now more important than quantity, because quality land can produce more with less manpower, less equipment, and less fertilizer. Bottomlands and alluvial soils adjacent to streams, if well drained and free from frequent flooding, are normally the most productive of all lands. But in many places throughout the United States such valley lands cannot now be used to their fullest extent, if at all, because of sedimentation, which obstructs drainage, increases flooding, and impairs soil fertility by overwashing the area with the infertile residue of soil erosion.

The research work of the Soil Conservation Service has indicated that sediment control measures, if properly applied, would prevent a large part of this damage, reclaim land already damaged, and protect irrigation and drainage developments. Methods of sediment control have not been as fully developed as many other soil and water conservation measures. Remedies for the sedimentation problem in each valley still require some individual study and treatment.

This publication presents basic experimental date on sediment transportation needs by technicians who must solve these practical sedimentation problems, and by research workers who are developing standard practices for control.

THE PROBLEM

With the exception of dissolved matter, the total solids load passing a particular cross section in a stream may be classified either as bed load or wash load, with a definite grain size representing the division between the two classes (11)[1]. The bed load is that part of the total solids load composed of the relatively coarse material (coarser than the division grain size). The bed load moves by rolling or sliding along the bed or by long jumps between points of contact with the bed while in temporary suspension at a rate related to the stream discharge. The wash load, except for a negligible percentage, moves entirely in suspension at a rate which bears no direct relation to discharge and is composed of the relatively fine material (finer than the division grain size). The wash load usually provides much the greater part of the material in a suspended-load sample taken at flood stage in a natural stream and may be looked upon as sediment in relatively permanent suspension.

The grain size, which divides the sediment load of a stream into the two classes, varies in different streams and generally throughout the length of a particular stream, although it has a definite value in a particular reach of a stream. The dividing grain size can be easily determined from the mechanical analysis curves of samples of material taken from the bed of a stream immediately after a flood. It is the finest grain size that occurs in the bed in appreciable quantities.

The available supply of bed material (coarse material) in a stream system changes but very slowly during a long period of years, if at all, and the quantity of material moved is mainly a response to discharge. The supply of wash material (fine material), however, may vary greatly from year to year and from season to season because of changing conditions of supply which are independent of conditions of flow. The most important variable of these completely interrelated conditions of supply are vegetal cover, tillage methods, stage of soil erosion, and climate.

Except for a few experiments conducted in natural streams with specially constructed traps (8, 31) and the recent studies of the Soil Conservation Service (6), quantitative studies of the transportation of sediment have been limited almost entirely to laboratory flumes. In no case, however, does it appear that the flume studies have included actual quantitative measurements of sediment in transit, in the form of bed load, in such streams as are large enough to be generally representative of rivers on which such knowledge is desired.

It is important to note that in the majority of laboratory investigations only the simplest type of bed-load transportation has been studied, namely, the material sliding or rolling along the bed. Very rarely have velocities been great enough in flume studies to cause an appreciable percentage of the bed material to be thrown into suspension. Only two investigations have been reported in which the effects of wash load accompanying bed movement was studied. One of these investigations was primarily concerned with a study of the scour of a sandy river bed by clear and by muddy water (37), and the other related to the effect of turbidity on the rate of bed-load movement (43).

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[1] Numbers in parentheses refer to Literature Cited, p. 54.

LABORATORY INVESTIGATIONS

Since the classic experiments by Gilbert (14) in 1914, a large number of investigations on bed-load transportation in flumes have been made at various laboratories throughout the world. Particular emphasis has been given to the study of (a) the critical conditions controlling the commencement of the movement of bed materials of various sizes, and (b) the rates of their movement. A few other related problems that have been studied are: Relation between the bed-roughness coefficient and particle size and other peculiarities of the bed, nonsilting channels in erodible materials, scour in river beds, sorting of sediments, and riffle formations.

The laboratory apparatus usually used has consisted of a circulating water-supply system, constant-head tank, weir box, stilling chamber, tilting flume (1 to 3 feet wide, and from 30 to 50 feet long), tail gate, and a return channel.

The usual experimental procedure consists of first placing sand in the flume to a depth of about two inches and molding the bed to a certain slope. Water is then allowed to pass through the flume under flow conditions made uniform by manipulation of the tail gate. At low discharges no movement of material occurs, but at a certain discharge, sediment movement begins and increases in rate as the discharge increases. A trap is provided at the downstream end of the flume to measure the rate of movement of material under test. In order to insure that no progressive change occurs in the elevation or slope of the bed during the course of a test, sand is introduced at the upper end of the flume to balance the amount that is moving, and hence is caught in the trap. Observations are made, during a test, on the hydraulic and sedimentary characteristics at various discharges above the critical discharge.

Critical Conditions for Movement

Observations indicate that certain conditions are necessary before the bed material in a stream is set in motion. Many investigations (4,5,12,13,14,15,16, 17,19,20,22,23,24,26,32,33,34,35,36; 38,39,41,44,45,46,47,48) have been made on materials of various size, shape, mechanical composition, and specific gravity to determine the critical conditions that create "general movement." General movement, as used in this sense, is that condition when sand grains up to and including the largest size available are in motion.

The condition required to produce movement of bed load may be defined by a critical term such as tractive force, discharge, mean velocity, bottom velocity, or some combination of certain other bydraulic and physical factors. The two most common procedures used in determining the value of the critical term for a particular material are:

(1) By first measuring the rate of bed-load transportation, as done by Gilbert (14), Schoklitsch (33), United States Waterways Experiment Station (36), and MacDougall (22), and then plotting this rate against measured values of tractive force, discharge, etc. A curve drawn through the plotted points and extended to the ordinate of zero transportation gives the critical value of the variable for the particular material.

(2) By measurement of certain hydraulic and physical factors when "general" movement is visually observed to occur. Kramer (20) and others (4,5) measured the slope and depth, while others (23,24,32; 48) measured the velocity gradient.

Some of the experiments for determining critical conditions have dealt with relatively uniform materials, while in others natural mixtures have been used. As would be expected, the critical point is less definite for mixtures because each size of material forming the mixture has its own characteristic critical value.

Most of the formulas developed in the earlier experiments contained certain constants, whose determination is almost impossible without first conducting flume tests on the particular material. Kramer (20) was the first to attempt to develop a practical formula for critical conditions in terms of sand size and distribution. In later investigations at the United States Waterways Experiment Station (36), Kramer's criteria and data were used and a modified formula was derived. More recently Chang (5) analyzed all available data and also presented a formula for critical tractive force in terms of the mechanical properties of the material.

Numerous experiments conducted at the University of Iowa (23,24,38) resulted in the establishment of a relationship between a competent bottom velocity, corresponding to impending motion of the stream bed, and the size and specific gravity of the bed material. Shields (35) conducted a series of experiments on the initial movement of uniform materials having a wide range in specific gravity and plotted his results according to an equation derived from theoretical considerations of fluid turbulence. The study of Shields is of importance because it emphasizes the great similarity of the functional trend to that of measurements in rough pipes and shows the effect of viscous action on the beginning of movement.

A summary of the most recent developments on the problem of defining critical conditions for bed-load movement may be found in the papers by Shields (35) and Chang (5). It is of interest to note, however, that because of the difficulty of accurately determining the critical value for incipient movement, O'Brien (27) amd Einstein (10) have found it convenient to dispense with the use of a critical factor in their formulas for bed-load transportation.

Rate of Bed-Load Transportation

The results of flume studies have been formulated to show the rate of transportation in terms of a variety of variables which the various investigators considered to best fit their data. Perhaps the most common type of formula used is a form of DuBoy's equation (7) in which rate of movement is plotted against a function of tractive force (5,24,35,36;38,45,47). Also very common in many investigations (4,13,14,19,22,25;39) is the Schoklitsch-Gilbert type in which slope, discharge, and grain size are considered of primary importance. In a few investigations (23,24,32;38,42,48), bed-load movement has been related to bottom velocity, and in others to mean velocity (26,27;39,48). More recently Einstein (10) has developed a dimensionless bed-load function from theoretical reasoning and experimental observations.

SUMMARY OF DATA ON BED ROUGHNESS AND RATE OF BED-LOAD TRANSPORTATION

The purpose of this report is not to discuss the conclusions of the various investigators, but instead to summarize the basic hydraulic and sedimentary data from all available published and unpublished flume experiments and present them in a uniform and consistent system of units. Data, which otherwise may not be readily available to all experimenters, are therefore presented in a usable and convenient form. In addition to the basic experimental data in each case, a brief description of the experimental equipment and procedure is also given.

Various experiments (20;42,48) have been made in which certain basic data were not observed because they were not considered essential in the particular studies, or because limitations in the experimental apparatus and procedure did not permit the observation to be made. In such cases no data have been included, but to make the report complete a brief description of the experimental equipment and procedure is given.

Summary of Physical Properties of Materials

Whenever possible, a plot of the mechanical composition is given for each material tested. A summary to show the mean diameter, phi[2] arithmetic mean diameter, phi[2] standard deviation, size limits, Kramer's uniformity modulus, and specific gravity is also included whenever the original data were complete enough to permit the various determinations.

Date Available for Summary

Most of the published (4,14,19,22,24,27,36) and unpublished (38,43,45,46,47,48) data from laboratories in the United States have been compiled in this summary. Certain experimental data, however, that were limited in value, as far as giving information on bed-load transportation or bed roughness, were not summarized, but in many cases a description of the experimental apparatus and procedure was abstracted (20,26,32;37;42,48).

To make the record as complete as possible, a brief description of the apparatus and procedure has been given for certain published investigations (5,25) where the experimental data are not available, because of unsettled European conditions. It is hoped that at a later date these data will become available and can be summarized and distributed as a supplement to the present compilation. It is also hoped that certain data (1,2,28) on the transportation of sand by wind will also become available.

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[2] The values of the various phi terms, defined by Krumbein (21) were determined by use of the logarithmic probability graph of Otto (29).

Table 1 gives an inventory of all the materials that have been tested in the various experiments referred to in the summaries of experimental data.

Summary of Experimental Data

The significance of the terms in the detailed summary of the test data is explained as follows:

Col. 1: Author's series or test number.
Col. 2: Author's run number.
Col. 3: Rate of water discharge, in cubic centimeters per second.
Col. 4: Width of flume, in centimeters.
Col. 5: Mean depth of flow, in centimeters.
Col. 6: Mean slope of the water surface, the bottom, or the energy gradient.
Col. 7: Temperature of water, in degrees centigrade.
Col. 8: Mean velocity, in centimeters per second.
Col. 9: Bottom velocity, in centimeters per second.
Col.10: Hydraulic radius of the sand bed, in centimeters.
Col.11: Friction velocity, in centimeters per second.
Col.12: Reynolds' number.
Col.13: Manning's n of the bed.
Col.14: Rate of discharge per unit width of bed, in cubic centimeters per second per centimeter.
Col.15: G = rate of bed-load transportation, in grams per second per centimeter.
Col.16: Duration of run, in minutes.
Col.17: Description of bed condition.

Sample Calculations

To illustrate the mechanics of the computations involved in reducing the various experimental data to the form described immediately above, observations from United Stated Waterways Experiment Station, Paper 17, are used (36). In run 25, table 11, the following data were observed.

Sand No. 1
Date of run: June 19, 1933
Width of flume = 2.416 feet
Discharge = 1.000 c.f.s.
Depth = 0.276 feet
Slope = 0.0010
Water temperature = 27° C.
Mean velocity = 1.50 feet per second
Rate of bed-load transportation = 9.9 pounds per foot per hour
Duration of run = 12 minutes
Bed condition: General riffles

Data for columns 1,2,6,7,16, and 17 are recorded directly from the original data. Other values were computed as follows:

Col. 3: Discharge:

$$Q = 1.000 \times (30.48)^3 = 28{,}317 \text{ cubic centimeters per second}$$

Col. 4: Width:
$B = 2.416 \times 30.48 = 73.6$ centimeters

Col. 5: Depth:
$D = 0.276 \times 30.48 = 8.41$ centimeters

Col. 8: Mean velocity:
$V_m = 1.50 \times 30.48 = 45.72$ centimeters

Col.10: Hydraulic radius of bed:
Calculated by the Einstein method (10) as follows: From tables 8, 9, and 10 of paper 17 the average Manning's n of the side wall is 0.0097 for turbulent flow.

From the various original data, the hydraulic radius of the wall is first calculated by Manning's formula:

$$r_{wall} = \left(\frac{n_{wall} \quad V_m}{4.641 \quad S^{1/2}} \right)^{3/2} = \left(\frac{0.0097}{4.641} \cdot \frac{45.72}{0.0316} \right)^{3/2} = 5.25 \text{ centimeters}$$

The area of the cross section pertaining to the wall is

$$a_{wall} = 2 \, D r_{wall}$$

The area of the cross section pertaining to the bed is

$$a_{bed} = D \, (B - 2 \, r_{wall})$$

and the corresponding hydraulic radius of the bed is:

$$r_{bed} = \frac{a_{bed}}{B} = D \left(1 - 2 \, \frac{r_{wall}}{B} \right)$$

$$= 8.41 \quad \left(1 - 2 \, \frac{5.25}{73.6} \right)$$

$$= 7.21 \text{ centimeters}$$

Col. 11: Friction velocity is defined as the square root of the ratio of tractive force on the bed to the density of water; that is

$$V^* = \sqrt{\frac{\tau_0}{\rho}}$$

$$\text{or} \qquad V^* = \sqrt{r_b \, g \, S}$$

$$= \sqrt{(7.21) \quad (980.6) \quad (0.0010)}$$

$$= \quad 2.66 \text{ centimeters per second}$$

Col. 12: Reynolds number

$$R = \frac{V_m \, r_b}{V}$$

$$= \frac{(45.72)(7.21)}{0.00852} = 38,690$$

Col. 13: Manning's n of bed.
By using the hydraulic radius r_b, the roughness factor n_{bed} is

$$n_{bed} = \frac{4.641}{V_m} \; r_b^{\;2/3} \; S^{1/2}$$

$$= \frac{4.641}{45.72} \; (7.21)^{2/3} \; (0.0010)^{1/2}$$

$$= 0.0120$$

Col. 14: Unit discharge.

$$q_b = V_m \, r_b$$

$= 45.72 \times 7.21 = 329.6$ cubic centimeters per second per centimeter

Col. 15: Rate of bed-load transportation

$$G = \frac{(9.9)(453.6)}{(3600)(30.48)}$$

$=$ 0.04093 grams per second per centimeter.

All computations have been made by calculating machine with the exception of square roots, and two-thirds and three-halves powers which were obtained by slide rule.

ACKNOWLEDGMENTS

The writer is greatly indebted to the various laboratories for having permitted the inclusion of many valuable data that as yet have not been published in full. Dr. H. A. Einstein contributed greatly with suggestions in connection with the general methods of presenting the data. Assistance in the preparation of the summary of bed-load data was furnished by the personnel of the Work Projects Administration Official Project No. 101-2-26-186.

TABLE I

SUMMARY OF MATERIALS TESTED IN BED-LOAD EXPERIMENTS

Item no.	Designation of material	Type of material	Specific gravity	Classification of mixture	Shape of particles	Mean diameter millimeters	Uniformity modulus, M	Tests conducted on		Data included in this summary	Reference*
								Critical conditions	Rate of transportation		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	Gilbert A	River sand	2.69	Uni-granular	Sub-angular	0.305		No	Yes	Yes	14
2	″ B	″	″	″	″	0.375		″	″	″	″
3	″ C	″	″	″	″	0.506		″	″	″	″
4	″ D	″	″	″	″	0.786		″	″	″	″
5	″ E	″	″	″	Sub-rounded	1.710		″	″	″	″
6	″ F	″	″	″	″	3.170		″	″	″	″
7	″ G	″	″	″	″	4.938		″	″	″	″
8	″ H	″	″	″	″	7.010		″	″	″	″
9	Mac Dougall I	Beach sand	–	Synthetic mixture	Rounded	0.66	0.654	Yes	″	″	22
10	″ II	″	–	″	″	1.01	0.491	″	″	″	″
11	″ III	″	–	″	″	1.44	0.423	″	″	″	″
12	Chyn 1	″	–	″	—	0.849	0.501	″	″	″	39
13	″ 2	″	–	″	—	0.840	0.747	″	″	″	″
14	″ 3	″	–	″	—	0.847	0.288	″	″	″	″
15	Jorissen I	″	2.67	″	—	0.72	0.354	″	″	″	19
16	″ II	″	2.67	″	—	0.93	0.495	″	″	″	″
17	U.S.W.E.S 1	River sand	2.65	Natural mixture	Sub-angular to sub-rounded	0.586	0.280	″	″	″	36
18	″ 2	″	″	″	″	0.541	0.439	″	″	″	″
19	″ 3	″	″	″	Sub-rounded to rounded	0.525	0.539	″	″	″	″
20	″ 4	″	″	″	Angular to sub-rounded	0.506	0.406	″	″	″	″
21	″ 5	″	″	″	Sub-angular to angular	0.483	0.438	″	″	″	″
22	″ 6	″	″	″	Sub-rounded to sub-angular	0.347	0.643	″	″	″	″
23	″ 7	″	″	″	″	0.310	0.525	″	″	″	″
24	″ 8	″	″	″	Sub-angular to angular	0.205	0.560	″	″	″	″
25	″ 9	″	″	″	Sub-rounded to sub-angular	4.077	0.566	″	″	″	″
26	″ 10	″	″	″	Sub-angular to angular	0.976	0.564	″	″	″	45
27	″ Turbidity	″	″	″	″	0.647	0.345	No	″	″	43
28	″ A	″	″	Synthetic mixture	Sub-angular to angular	0.853	0.666	″	″	″	47
29	″ B	″	″	″	″	0.794	0.603	″	″	″	″
30	″ C	″	″	″	″	0.715	0.536	″	″	″	″
31	″ D	″	″	″	″	1.224	0.689	″	″	″	″
32	″ E	″	″	″	″	1.162	0.636	″	″	″	″
33	″ F	″	″	″	″	1.008	0.546	″	″	″	″
34	″ G	″	″	″	″	0.986	0.628	″	″	″	″
35	″ H	″	″	″	″	1.067	0.496	″	″	″	″
36	″ I	″	″	″	″	1.052	0.461	″	″	″	″
37	″ J	″	″	″	″	1.066	0.424	″	″	″	″
38	″ K	″	″	″	″	0.732	0.636	″	″	″	″
39	″ L	″	″	″	″	0.738	0.503	″	″	″	″
40	″ M	″	″	″	″	0.759	0.475	″	″	″	″
41	″ U 0.295	″	″	Uni-granular	″	0.367	0.752	″	″	″	″
42	″ U 0.417	″	″	″	″	0.498	0.791	″	″	″	″
43	″ U 0.589	″	″	″	″	0.691	0.774	″	″	″	″
44	″ U 0.833	″	″	″	″	0.976	0.786	″	″	″	″
45	″ Fitler	″	″	Natural mixture	″	0.597	0.369	″	″	″	″
46	″ U 0.056	Gravel	″	Uni-granular	Sub-rounded	1.42	—	Yes	No	No	44
47	″ U 0.079	″	″	″	″	2.01	—	″	″	″	″
48	″ U 0.112	″	″	″	″	2.84	—	″	″	″	″
49	″ U 0.158	″	″	″	″	4.01	—	″	″	″	″
50	″ U 0.224	″	″	″	″	5.69	—	″	″	″	″
51	″ U 0.317	″	″	″	″	8.05	—	″	″	″	″
52	″ U 0.448	″	″	″	″	11.4	—	″	″	″	″
53	″ U 0.650	″	″	″	″	16.5	—	″	″	″	.
54	″ U 0.97	″	″	″	″	24.4	—	″	″	″	″
55	″ U 1.55	″	″	″	″	39.4	—	″	″	″	″
56	″ U 1.95	″	″	″	″	49.5	—	″	″	″	″
57	″ U 2.30	″	—	″	″	58.4	—	″	″	″	″
58	″ H-1	Haydite	1.85	Commercial mixture	Angular	1.067	0.378	″	Yes	Yes	46
59	″ H-2	″	1.85	″	″	0.908	0.401	—	″	″	″
60	″ H-3	″	1.74	″	″	1.329	0.365	″	″	″	″
61	″ C-1	Coal	1.35	Mixture resulting from crushing	″	3.300	0.399	—	—	″	″
62	″ C-2	″	1.35	″	″	1.097	0.341	″	—	″	″
63	″ C-3	″	1.32	″	″	3.197	0.466	″	″	″	″

* Reference number refers to items in literature cited.

TABLE I

SUMMARY OF MATERIALS TESTED IN BED-LOAD EXPERIMENTS

Item no.	Designation of material	Type of material	Specific gravity	Classification of mixture	Shape of particles	Mean diameter millimeters	Uniformity modulus, M	Tests conducted on: Critical conditions	Tests conducted on: Rate of transportation	Data included in this summary	Reference*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
64	U.S.W.E.S. C-4	Coal	1.32	Mixture resulting from crushing	Angular	1.485	0.518	Yes	Yes	No	46
65	" C-5	"	1.31	"	"	2.610	0.287	"	"	"	"
66	" C-6	"	1.31	"	"	1.168	0.397	"	"	"	"
67	" C-7	Flake pitch	1.26	"	"	3.963	0.485	"	"	"	"
68	" C-8	" "	1.26	"	"	1.147	0.372	"	"	"	"
69	" R-1	Rosin	1.11	"	"	2.777	0.305	"	"	"	"
70	" R-2	"	1.11	"	"	1.317	0.440	"	"	"	"
71	" G-1	Gilsonite	1.07	"	"	3.553	0.398	"	"	"	"
72	" G-2	"	1.07	"	"	0.899	0.372	"	"	"	"
73	" G-3	"	1.05	"	"	3.526	0.366	"	"	"	"
74	" G-4	"	1.05	"	"	1.249	0.524	"	"	"	"
75	" G-5	"	1.03	"	"	3.112	0.286	"	"	"	"
76	" G-6	"	1.03	"	"	1.165	0.441	"	"	"	"
77	Ho I.R.S. - 5.7	River sand	2.65	Uni-granular	—	5.7	0.84	"	No	"	23
78	" " - 4.0	" "	2.65	"	—	4.0	"	"	"	"	"
79	" " - 2.8	" "	2.66	"	—	2.8	"	"	"	"	"
80	" " - 2.0	" "	2.62	"	—	2.0	"	"	"	"	"
81	" " - 1.4	" "	2.63	"	—	1.4	"	"	"	"	"
82	" " - 1.0	" "	2.63	"	—	1.0	"	"	"	"	"
83	" " - 0.7	" "	2.68	"	—	0.7	"	"	"	"	"
84	" " - 0.5	" "	2.62	"	—	0.5	"	"	"	"	"
85	" " - 0.35	" "	2.62	"	Angular	0.35	"	"	"	"	"
86	" C.L. - 5.7	Crushed limestone	2.66	"	"	5.7	"	"	"	"	"
87	" " - 4.0	"	2.66	"	"	4.0	"	"	"	"	"
88	" H - 2.0	Haydite	1.81	"	"	2.0	"	"	"	"	"
89	" " - 1.4	"	1.78	"	"	1.4	"	"	"	"	"
90	" " - 1.0	"	1.83	"	"	1.0	"	"	"	"	"
91	" " - 0.7	"	1.88	"	"	0.7	"	"	"	"	"
92	" " - 0.5	"	1.86	"	"	0.5	"	"	"	"	"
93	" Knox	Dune sand	2.54	Natural mixture	—	0.15	1.68	"	"	"	"
94	Liu & Carter D	River sand	2.64	Synthetic mixture	Rounded	2.9	0.83	"	Scour	"	42
95	" " E	" "	2.58	" "	"	1.4	0.74	"	"	"	"
96	" " I	Crushed limestone	2.69	" "	Angular	2.8	0.73	"	"	"	"
97	" " II	"	2.69	" "	"	5.5	0.76	"	"	"	"
98	Liu I	River sand	2.66	" "	Rounded	4.4	0.72	"	Yes	Yes	24
99	" II	" "	2.66	" "	"	3.4	0.71	"	"	"	"
100	" III	" "	2.66	" "	"	2.3	0.68	"	"	"	"
101	" IV	" "	2.66	" "	"	1.4	0.67	"	"	"	"
102	" V	" "	2.66	" "	"	3.6	0.66	"	"	"	"
103	" VI	" "	2.66	" "	"	1.8	0.58	"	"	"	"
104	Bogardi & Yen I	Gravel	2.63	Uni-granular	Well rounded	10.56	0.86	"	"	"	38
105	" " II	"	2.61	"	" "	7.12	0.75	"	"	"	"
106	" " III	"	2.64	"	" "	15.49	0.86	"	"	"	"
107	Columbia River	River sand	2.57	Natural mixture	Sub-angular	0.366	0.486	"	"	"	27
108	Wright-Asphalt Sand 1	Sand	—	" "	"	0.336	0.333	"	Scour	No	37
109	" " " 2	"	—	Synthetic mixture	"	0.204	—	"	"	"	"
110	" " " 3	"	—	" "	"	0.384	—	"	"	"	"
111	" Colorado	River sand	—	Natural mixture	"	0.112	0.50	"	"	"	"
112	Linton S.M 1-1	Gravel	2.72	Uni-granular	Sub-rounded	31.75	—	"	No	See Table 18	48
113	" " 2-1	"	2.72	"	"	31.75	—	"	"		"
114	" " 3-1	"	2.65	"	"	22.23	—	"	Yes		"
115	" " 4-1	"	2.65	"	"	22.23	—	"	No		"
116	" " 4-2	"	2.65	"	"	22.23	—	"	"		"
117	" " 5-1	"	2.67	"	"	15.88	—	"	Yes		"
118	" " 5-2	"	2.67	"	"	15.88	—	"	"		"
119	" " 6-1	"	2.67	"	"	15.88	—	"	"		"
120	" " 6-2	"	2.67	"	"	15.88	—	"	"		"
121	" " 6-3	"	2.67	"	"	15.88	—	"	"		"
122	" " 7-1	"	2.67	"	"	11.11	—	"	"		"
123	" " 7-2	"	2.67	"	"	11.11	—	"	"		"
124	" " 7-3	"	2.67	"	"	11.11	—	"	"		"
125	" " 8-1	"	2.70	"	"	10.48	—	"	"		"
126	" " 8-2	"	2.70	"	"	10.48	—	"	"		"

* Reference number refers to items in literature cited.

TABLE I
SUMMARY OF MATERIALS TESTED IN BED-LOAD EXPERIMENTS

Item no.	Designation of material	Type of material	Specific gravity	Classification of mixture	Shape of particles	Mean diameter millimeters	Uniformity modulus, M	Tests conducted on: Critical conditions	Tests conducted on: Rate of transportation	Data included in this summary	Reference*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
127	Linton S.M. 8-3	Gravel	2.70	Uni-granular	Sub-rounded	10.48	—	Yes	Yes	See Table 18	48
128	" " 9-1	"	2.72	"	" "	31.75	—	"	"		"
129	" " 10-1	"	2.70	"	" "	63.50	—	"	"		"
130	" " 11-1	"	"	"	" "	63.50	—	No	"		"
131	" " 12-1	Crushed rock	2.74	"	Angular	63.50	—	Yes	"		"
132	" " 13-1	"	"	"	"	63.50	—	"	"		"
133	" " 14-1	Gravel	2.71	"	Sub-rounded	88.90	—	"	"		"
134	" " 15-1	"	2.62	"	" "	114.30	—	"	"		"
135	" " 16-1	"	2.70	"	" "	139.70	—	"	"		"
136	" " 17-1	Crushed rock	2.76	"	Angular	88.90	—	"	"		"
137	" " 18-1	Gravel	2.72	"	Sub-rounded	31.75	—	"	"		"
138	Schaffernak I-3	"	2.7	"	Round and flat	3	1.0	"	Scour only	No	32
139	" I-5	"	"	"	" " "	5	1.0	"	"	"	"
140	" I-10	"	"	"	" " "	10	1.0	"	"	"	"
141	" I-12	"	"	"	" " "	12	1.0	"	"	"	"
142	" I-14	"	"	"	" " "	14	1.0	"	"	"	"
143	" I-16	"	"	"	" " "	16	1.0	"	"	"	"
144	" I-20	"	"	"	" " "	20	1.0	"	"	"	"
145	" I-25	"	"	"	" " "	25	1.0	"	"	"	"
146	" I-30	"	"	"	" " "	30	1.0	"	"	"	"
147	" I-50	"	"	"	" " "	50	1.0	"	"	"	"
148	" I-70	"	"	"	" " "	70	1.0	"	"	"	"
149	" II 0-3	"	"	Synthetic mixtures	" " "	2.35	0.64	"	"	"	"
150	" II 0-5	"	"	"	" " "	3.93	"	"	"	"	"
151	" II 0-10	"	"	"	" " "	7.85	"	"	"	"	"
152	" II 0-16	"	"	"	" " "	12.57	"	"	"	"	"
153	" II 0-20	"	"	"	" " "	15.71	"	"	"	"	"
154	" II 0-30	"	"	"	" " "	23.51	"	"	"	"	"
155	" II 0-50	"	"	"	" " "	39.27	"	"	"	"	"
156	" III 0-3	"	"	"	" " "	1.5	0.333	"	"	"	"
157	" III 0-5	"	"	"	" " "	2.5	"	"	"	"	"
158	" III 0-10	"	"	"	" " "	5.0	"	"	"	"	"
159	" III 0-16	"	"	"	" " "	8.0	"	"	"	"	"
160	" III 0-20	"	"	"	" " "	10.0	"	"	"	"	"
161	" III 0-30	"	"	"	" " "	15.0	"	"	"	"	"
162	" III 0-50	"	"	"	" " "	25.0	"	"	"	"	"
163	" IV 0-3	"	"	"	" " "	0.64	0.112	"	"	"	"
164	" IV 0-5	"	"	"	" " "	1.07	"	"	"	"	"
165	" IV 0-10	"	"	"	" " "	2.15	"	"	"	"	"
166	" IV 0-16	"	"	"	" " "	3.43	"	"	"	"	"
167	" IV 0-20	"	"	"	" " "	4.29	"	"	"	"	"
168	" IV 0-30	"	"	"	" " "	6.44	"	"	"	"	"
169	" IV 0-50	"	"	"	" " "	10.73	"	"	"	"	"
170	Meyer-Peter G-28.6	"	2.65	Uni-granular	Well-rounded	28.6	0.84	No	Yes	"	25
171	" G-5.21	"	"	"	" "	5.21	0.84	"	"	"	"
172	" C-5.21	Coal	1.25	"	Angular	5.21	0.84	"	"	"	"
173	" B-5.21	Barite	4.22	"	"	5.21	0.84	"	"	"	"
174	Kramer I	Sand	2.70	Natural mixtures	Well-rounded	0.705	0.358	Yes	No	"	20
175	" II	"	"	"	" "	0.558	0.461	"	"	"	"
176	" III	"	"	"	" "	0.800	0.414	"	"	"	"
177	Casey a	"	–	Uni-granular	Sub-angular to rounded	0.175	0.716	"	Yes	"	4
178	" b	"	–	"		0.263	0.645	"	"	"	"
179	" c	"	–	"	" "	0.68	0.804	"	"	"	"
180	" d	"	–	"	" "	0.87	0.830	"	"	"	"
181	" e	"	–	"	" "	0.938	0.799	"	"	"	"
182	" f	"	–	"	" "	1.26	0.812	"	"	"	"
183	" g	"	–	"	" "	1.747	0.790	"	"	"	"
184	" h	"	–	"	" "	2.455	0.789	"	"	Yes	"
185	" I A	"	–	Synthetic mixtures	" "	0.50	0.235	"	"	No	"
186	" II A	"	–	"	" "	0.92	0.145	"	"	"	"
187	" III A	"	–	"	" "	1.32	0.147	"	"	Yes	"
188	" I B	"	–	"	" "	0.52	0.296	"	"	No	"
189	" II B	"	–	"	" "	0.90	0.359	"	"	"	"

*Reference number refers to items in literature cited.

TABLE I
SUMMARY OF MATERIALS TESTED IN BED-LOAD EXPERIMENTS

Item no.	Designation of material	Type of material	Specific gravity	Classification of mixture	Shape of particles	Mean diameter millimeters	Uniformity modulus, M	Tests conducted on		Data included in this summary	Reference *
								Critical conditions	Rate of transportation		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
190	Casey III B	Sand	—	Synthetic mixtures	Sub-angular to rounded	1.37	0.303	Yes	Yes	No	4
191	" I C	"	—	"		0.53	0.465	"	"	"	"
192	" II C	"	—	"	"	0.90	0.677	"	"	"	"
193	" III C	"	—	"	"	1.25	0.492	"	"	"	"
194	Shields - Amber	Amber	1.06	Mixture from crushing	Angular	1.56	0.58	"	"	"	35
195	" B.C-I	Brown Coal	1.27	"	"	1.77	0.39	"	"	"	"
196	" B.C-II	" "	1.27	"	"	1.88	0.39	"	"	"	"
197	" B.C-III	" "	1.27	"	"	2.53	0.55	"	"	"	"
198	" G.F-I	Granite frag	2.69	Uni-granular	"	2.44	0.79	"	"	"	"
199	" G.F-II	" "	2.71	"	"	1.23	0.83	"	"	"	"
200	" G.F-III	" "	2.70	"	"	0.85	0.81	"	"	"	"
201	" B-I	Barite	4.2	"	"	3.44	0.82	"	"	"	"
202	" B-II	"	4.19	"	"	2.46	0.78	"	"	"	"
203	" B-III	"	4.2	"	"	1.52	0.67	"	"	"	"
204	" B-IV	"	4.25	"	"	0.69	0.67	"	"	"	"
205	" B-V	"	4.3	"	"	0.36	0.67	"	"	"	"
206	" B-VI	"	4.2	"	"	2.76	0.68	"	"	"	"
207	Ho Pang-Yung I	Gravel	2.58	Synthetic mixture	Flat	3.83	0.313	"	"	Yes	15
208	" " " II	"	2.58	"	"	4.64	0.502	"	"	"	"
209	" " " III	"	2.58	"	"	6.99	0.530	"	"	"	"
210	" " " IV	"	2.58	"	"	2.18	0.372	"	"	"	"
211	" " " V	"	2.58	"	"	6.17	0.624	"	"	"	"
212	" " " VI	Sand	—	Synthetic mixture	Rounded	1.55	0.371	"	"	"	"
213	Chang 6205	"	2.547	Uni-granular	—	8.090	1.000	"	"	No	5
214	" 6204	"	2.558	"	—	6.540	"	"	"	"	"
215	" 6203	"	2.567	"	—	5.290	"	"	"	"	"
216	" 6202	"	2.590	"	—	3.770	"	"	"	"	"
217	" 6201	"	2.633	"	—	2.540	"	"	"	"	"
218	" 6200	"	2.634	"	—	1.760	"	"	"	"	"
219	" 6199	"	2.640	"	—	0.886	"	"	"	"	"
220	" 6198	"	2.643	"	—	0.396	"	"	"	"	"
221	" 6197	"	2.645	"	—	0.226	"	"	"	"	"
222	" Pumice	Pumice	2.053	"	—	0.289	"	"	"	"	"
223	" Emery	Emery	3.890	"	—	0.210	"	"	"	"	"
224	" Sand α	Sand	2.520	"	—	0.134	"	"	Yes	"	"
225	Indri - 1	Beach sand	2.63	Natural mixture	—	0.324	0.690	"	No	"	16
226	" - 2	Sand	2.70	" "	—	0.474	0.481	"	"	"	"
227	" - 3	Gravel	2.70	Uni-granular	—	2.5	0.818	"	"	"	"
228	" - 4	"	2.70	"	—	4.0	0.777	"	"	"	"
229	" - 1	"	2.65	"	Rounded	20	0.600	"	"	"	17
230	" - 2	"	2.65	"	"	45	0.715	"	"	"	"
231	" - 3	"	2.65	"	"	80	0.770	"	"	"	"
232	" - 4	"	2.65	"	"	125	0.815	"	"	"	"
233	" - 5	"	2.65	Synthetic mixture	"	58.8	0.225	"	"	"	"
234	" - 6	"	2.65	"	"	58.8	0.280	"	"	"	"
235	Nakayama A	Sand	—	"	—	1.07	0.46	"	Scour	"	26
236	" B	"	—	"	—	0.36	0.66	"	"	"	"
237	" C	"	—	"	—	3.43	0.64	"	"	"	"
238	" D	"	—	"	—	—	—	"	"	"	"

* Reference number refers to items in literature cited.

EXPERIMENTS BY G. K. GILBERT

Mr. Gilbert (14) has recorded and discussed a series of experiments made in a specially equipped laboratory at the University of California, Berkeley, in the years 1907-1909. The majority of experiments were concerned with the movement of sands of uniform grain sizes, and both stream traction and flume traction were studied.

Experimental Equipment and Measurements

The flume used in the majority of the experiments (fig. 1) was built of planed and painted wood with a length of 31.5 feet, an average depth of 1.4 feet, and a width adjustable between 0.23 and 1.96 feet. The depth of flow was controlled by contractions on the outfall end. Rate of sand transportation was measured by a trap located upstream from the contraction.

Water was circulated by pumping from a sump and the discharge through the flume was measured by a calibrated orifice. Depths were measured by a point gage and slopes by a surveyor's level over a 16-foot reach near the center of the flume. Ordinarily, only the bed slope was measured; however, in some instances a water-surface profile was obtained. Some measurements of velocity were attempted with a Pitot tube, but, in general, only the mean velocity was calculated from the measured values of discharge, width, and depth.

Materials Tested

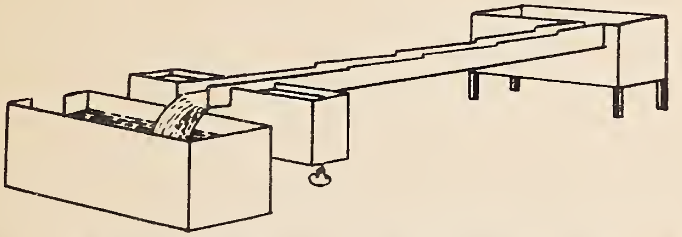
The sand and gravel used in the experiments was obtained from 3 California streams, the Sacramento River 6 miles above the mouth of the American, the American River 8 miles above its mouth, and Strawberry Creek in Berkeley. The material from Strawberry Creek was relatively coarse and was used only in the experiments on flume traction. The specific gravities were 2.69 for the river material and 2.53 for the creek gravel.

The material was sorted by means of sieves and each grade consisted of material passing one sieve and caught on the next in the series. Eleven different grades, designated by the letters A, B, C, D, E, F, G, H, I, J, and K were obtained. The sieve numbers used in the separation and the mean diameter of the particles are summarized in table 2. The mean diameter in this instance is defined as the diameter of a sphere having the volume of the average particle.

Table 2.--Summary of sands tested by Gilbert

Grade	Sieves used in separating (meshes to 1 inch)	Mean diameter
		Millimeters
A.	50-60	0.305
B.	40-50	.375
C.	30-40	.506
D.	20-30	.786
E.	10-20	1.710
F.	6-8	3.170
G.	4-6	4.938
H.	3-4	7.010
I.	1-2	16.673
J.	1/2-1	33.528
K.	1/3-1/2	60.960

Figure 1



Diagrammatic view of shorter experiment trough, showing relations to stilling tank, cross tank, and settling tank

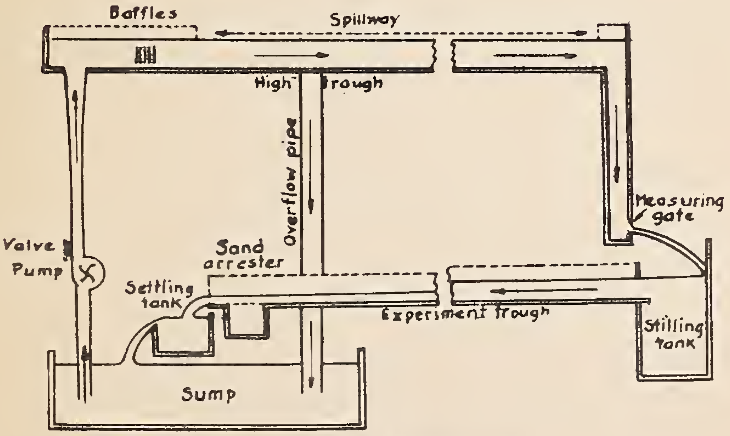


Diagram of water circuit

APPARATUS OF G.K.GILBERT

Experimental Procedure

A chosen width of flume was provided by adjustment of a longitudinal partition. Flow was started and the measuring orifice adjusted to give a desired discharge. The outfall contractor was adjusted to a width previously found suitable for the conditions of the experiment. When the flow became steady, sand was fed into the stream from a special hopper. Flow in the flume and the introduction of sand were continued without change until the slope of the deposit forming the channel bed had become stable. When this condition was reached a load measurement was made by placing a box in the sand trap and collecting sand over a period of time, which usually ranged from 3 to 10 minutes. In a few cases collection periods up to 7 hours were recorded. During the period of load measurement the depth of flow and, under certain conditions, the slope of the water surface were measured, and the character of the sand bed recorded. At the conclusion of a load measurement, the flow in the system was stopped and the slope of the sand bed measured. The sand caught in the trap was drained of excess water and weighed without drying and a correction for dry weight applied. This correction factor, however, could not be located in the report.

Although there were some variations, this was the usual procedure in most of the tests. In some runs at high rates of bed movement, the material was fed in by hand. It was found that only with the finest sediments and at the highest rates of discharge was the amount of material carried past the trap too large to be neglected.

Other Experiments

In addition to the numerous tests on sands of uniform grain size, Gilbert also performed a few experiments on mixtures. The data from the tests on mixtures, however, are of limited value because the depth of flow was not observed in most instances.

In addition to the great majority of the experiments wherein transportation took place along a bed of the same material being transported, a number of tests were reported in which the bottom of the flume was kept free of sediment; that is, transportation by flume traction. Investigations were made of the movement of sediment over a floor of planed and painted wood of rough-sawed wood, over wooden blocks with grain vertical, over a pavement of sand grains set in cement, and over a pavement of pebbles set in cement. Sand grades, B, C, E, G, H, I, and J (table 2) and three mixtures were used in these studies. A few minor experiments with crooked channels were conducted on sand grade C to show the influence of bends on traction.

Data Appearing in Summary

Only those data appearing in tables 4A to 4I, inclusive, of Gilbert's paper are summarized in table 27. These data pertain to experiments in which sands of grades A to H, inclusive, (items 1-8, table 1) were transported by stream traction with all measurements being made according to the experimental procedure previously described.

Data on the transportation of mixtures, flume traction, and crooked channels have not been included because either certain pertinent data were lacking or the results were special cases which contributed very little to the general problems of bed-load transportation and bed roughness.

Because Gilbert did not number his experiments in his report, all experiments without any omissions are given in table 27 in the order in which they appear in tables 4A to 4I, inclusive, of the original paper. Even though data are lacking in many of the experiments and consequently all columns could not be completed, it is believed that this method of listing will permit the most convenient comparison between the original and computed data when desired.

In reducing the original data to conform with the following summary the same procedure as outlined in the sample calculation on pages 5 to 7 was followed. In all calculations involving a slope term the bed slope was used, the assumption being that the bed slope was parallel to the slope of the energy gradient. That this assumption is not always valid is evidenced in some cases by absurd values of the bed roughness (column 13, table 27). In computing the hydraulic radius of the bed (column 10) a Manning's n of 0.00909 for the side walls was assumed. Also since no water temperatures were recorded, an average kinematic viscosity of 0.0100 square centimeter per second was assumed in computing Reynolds number (column 12).

EXPERIMENTS BY C. H. MACDOUGALL.

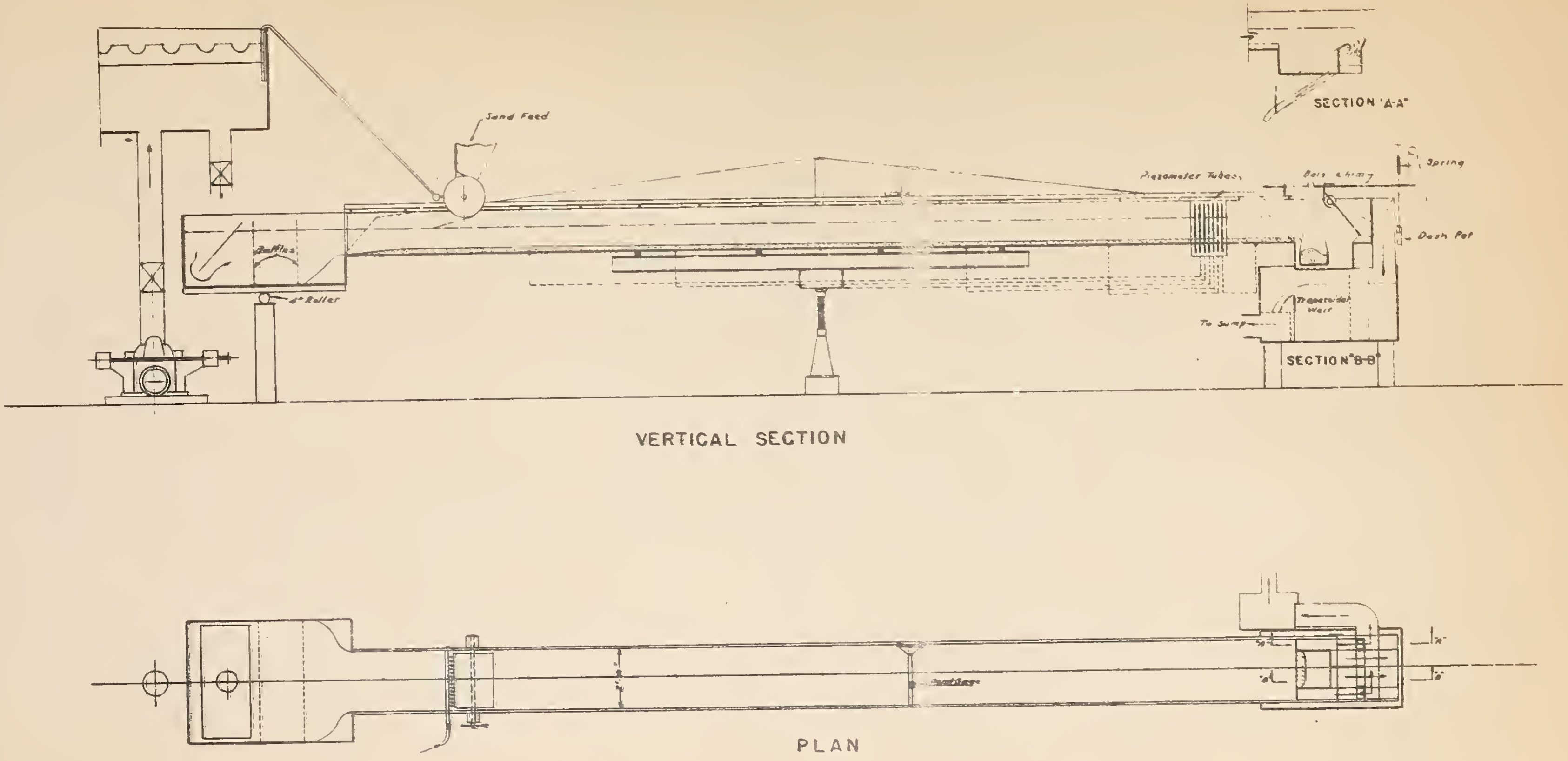
These experiments (22), were made under the auspices of the Civil and Sanitary Engineering Department at the Massachusetts Institute of Technology as part of a systematic program of research planned to investigate a series of synthetic sand mixtures, each within as wide a range of flow conditions as possible.

Experimental Equipment and Measurements

The apparatus shown in figure 2 consisted of a 32-foot tilting flume 24 inches wide and 15 inches deep, constructed of redwood, and equipped with an automatic sand-feeding device, a chronographic recorder for measurement of sand discharge, and methods for controlling the slope, depth, and discharge of water. To permit the elimination of the effect of side-wall friction, the lower end of the flume was divided into three sections by longitudinal plates so that the sand and water from the central section could be measured separately while the flow along the sides was wasted. The water discharged from the central section flowed into a tank, directly below the flume, and was measured by a trapezoidal weir.

The slope and depth of water in the flume were measured by means of a series of piezometer openings spaced at 1.5-meter intervals along the center line of the flume. These openings were connected by rubber tubing to a bank of glass standpipes at the lower end of the channel. Observation of the water levels in these piezometers enabled the experimenter to adjust the water-surface slope by manipulation of the tail gate on the outlet of the flume.

Figure 2

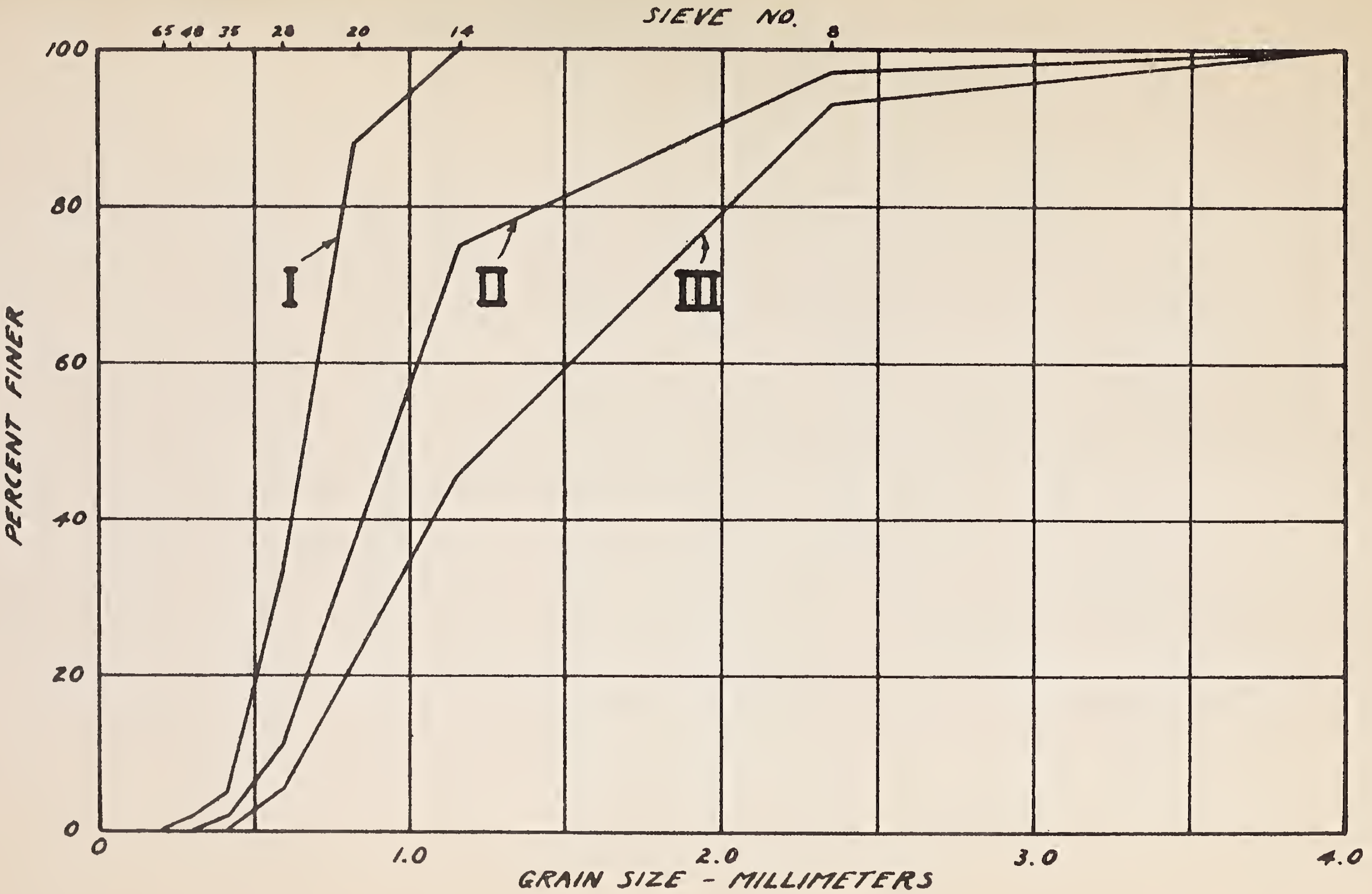


VERTICAL SECTION

PLAN

APPARATUS OF McDOUGALL, CHYN, AND JORISSEN

Figure 3



MATERIALS TESTED BY MACDOUGALL

Material Tested

Three synthetic mixtures (items 9-11, table 1) prepared from a round-grained quartz beach sand were used in these experiments. The mechanical analysis curves of the three mixtures are shown in figure 3, and table 3 summarizes the physical properties of each material.

Table 3.—Summary of physical properties of materials tested by MacDougall

Material	Size limits	Diameter		Phi standard deviation	Uniformity modulus
		Mean	Phi arithmetic mean		
	Millimeters	Millimeters			
I....	0.208-1.168	0.66	+0.66	0.35	0.654
II...	.295-4.699	1.01	+0.06	.58	.491
III..	.417-4.699	1.44	-0.280	.66	.423

Experimental Procedure

The flume and the rails along its edge were adjusted to a desired slope, and the sand mixture to be tested was placed in the flume bottom and leveled off to the same slope by means of a scraper moved on the rails. The flume was then flooded, but the flow was kept below that required to move the sand. After flooding, the flow was increased until movement of the sand began. The water surface slope was adjusted by the tail gate, the discharge was measured, and the automatic weighing of the bed load was begun and continued until a sufficiently long record was obtained. The water depth was recorded from the piezometers. With the water-surface slope kept constant, sand was added at the upper end of the flume at such a rate that the bed level remained constant.

At the conclusion of a run, the bottom was releveled and the experiment repeated with another discharge.

Data Appearing in Summary

All experimental data appearing in table 45, appendix I, of a report of research carried on in the River Hydraulic Laboratory of the Massachusetts Institute of Technology, 1932-33 are summarized in table 28. These data covered tests on 3 synthetic sand mixtures, each tested at slopes of 1:300, 1:600, and 1:900. Where possible computations were made according to the sample calculations on pages 5 to 7. The lack of certain basic data made it necessary to omit from the summary the total discharge from column 3, the temperature from column 7, the bottom velocity from column 9, the length of run from column 16, and the condition of the bed from column 17. Since the mean velocity (column 8) was computed by the author from the discharge, depth, and width of the flow in the central portion of the flume, it was not considered significant to attempt to compute the hydraulic radius of the bed (column 10). In the event that the missing data were available an interesting comparison could be made between elimination of side-wall effect by the computed method of Einstein (page 6), and by the use of the division plates at the lower end of the flume. The values of friction velocity (column 11), Reynolds number (column 12) and Manning's n of the bed (column 13), all were computed by assuming the hydraulic radius of the bed to be equal to the mean water depth (column 5). Since no water temperatures were given, a value of 0.0100 square centimeter per second for the kinematic viscosity was used in computing Reynolds number. The unit discharge (column 14) was obtained directly from the author's values which were originally computed from the measured discharge through the central portion of the flume.

EXPERIMENTS BY S. D. CHYN

These experiments (39) were a continuation of the work started by C. H. MacDougall of the Department of Civil and Sanitary Engineering at the Massachusetts Institute of Technology. The primary object of the present investigation was to determine to what extent and in what manner the sand composition affects the total amount of material transported along the bed of a stream. The problem of sorting also was studied.

Experimental Equipment and Measurements

Same as that of MacDougall, (see fig. 2 and description on page 14).

Material Tested

Three synthetic mixtures (items 12-14, table 1) prepared from sieve separates of Plum Island sand were used in these experiments. The mixtures had approximately equal mean grain diameters but widely varying values of uniformity modulus. The mechanical analysis curves of the 3 mixtures are shown in figure 4, and table 4 summarizes the physical properties of each material.

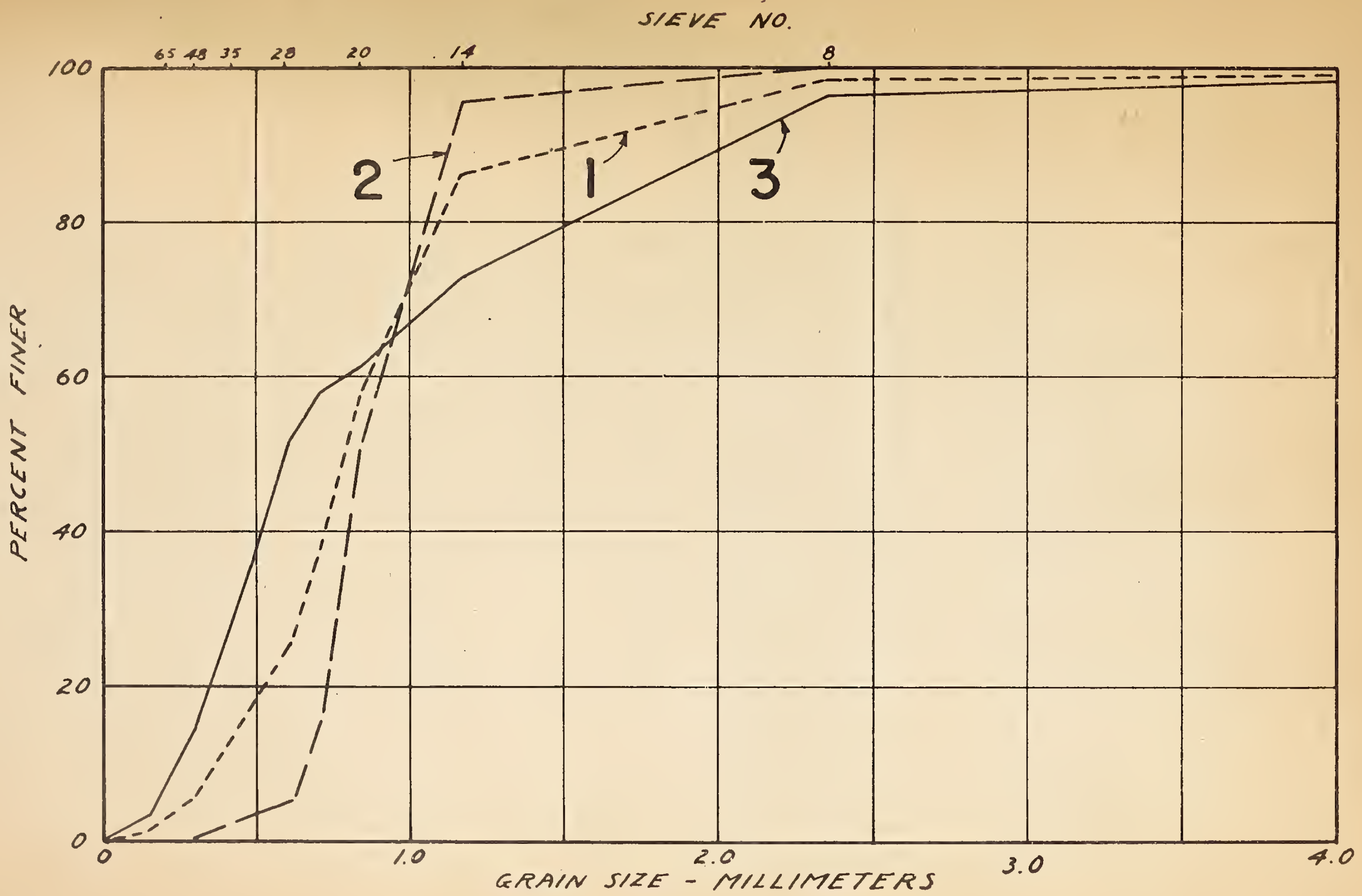
Table 4.--Summary of physical properties of materials tested by Chyn

Material	Size limits	Diameter		Phi standard deviation	Uniformity modulus
		Mean	Phi arithmetic mean		
	Millimeters	Millimeters			
1......	0.147-4.699	0.849	+0.40	0.60	0.501
2......	.295-2.362	.840	+ .25	.27	.747
3......	.147-4.699	.847	+ .56	—	.288

Experimental Procedure

Same as that of MacDougall (see page 15).

Figure 4



MATERIALS TESTED BY CHYN

Data Appearing in Summary

All experimental data recorded in tables I to IV, inclusive, of the original thesis are summarized in table 29. These data covered tests on the 3 synthetic sand mixtures at slopes ranging from 1:300 to 1:900. Where possible, computations were made according to the method outlined by the sample calculation on pages 5 to 7. The lack of certain basic data made it necessary to omit from the summary the total discharge from column 3, the bottom velocity from column 9, and the length of run from column 16. Since the mean velocity (column 8) was computed by the author from the discharge, depth, and width of flow in the central portion of the flume, it was not considered significant to attempt to compute the hydraulic radius of the bed (column 10). The values of friction velocity (column 11), Reynolds number (column 12) and Manning's n of the bed (column 13), all were computed by assuming the hydraulic radius of the bed to be equal to the mean water depth (column 5). The unit discharge (column 14) was obtained directly from the author's values which were originally computed from the measured discharge through the central portion of the flume.

EXPERIMENTS BY A. L. JORISSEN

These experiments (19) were a continuation of the previous work by C. H. MacDougall and S. D. Chyn of the Department of Civil and Sanitary Engineering at the Massachusetts Institute of Technology. The purpose of the present study was to investigate two sand mixtures and analyze to what extent the mechanical composition of the sand and its compactness affect the capacity of bed-load transportation.

Experimental Equipment and Measurements

Same as that of MacDougall (see fig. 2 and description on p. 14).

Material Tested

Two synthetic mixtures (items 15 and 16, table 1) prepared from sieve separates of Plum Island sand were used in these experiments. The mechanical analysis curves of the two mixtures are shown in figure 5, and table 5 summarizes physical properties of each material.

Table 5.—Summary of physical properties of materials tested by Jorissen

Material	Specific gravity	Size limits	Diameter: Mean	Diameter: Phi arithmetic mean	Phi standard deviation	Uniformity modulus
		Millimeters	Millimeters			
I	2.67	0.147-4.699	0.72	0.68	0.81	0.354
II	2.67	.147-4.699	.93	.93	.55	.495

Experimental Procedure

Same as that of MacDougall (see p. 15).

Data Appearing in Summary

All experimental data recorded in table 2 of the original thesis are summarized in table 30. These data covered tests on the two synthetic sand mixtures at slopes ranging from 1:300 to 1:900. Where possible, computations were made according to the method outlined by the sample calculation on pages 5 to 7. The lack of certain basic data made it necessary to omit from the summary the total discharge from column 3, the bottom velocity from column 9, and the length of run from column 16. Since the mean velocity (column 8) was computed by the author from the discharge, depth, and the width of the flow in the central portion of the flume, it was not considered significant to attempt to compute the hydraulic radius of the bed (column 10). The values of friction velocity (column 11), Reynolds number (column 12), and Manning's n of the bed (column 13), all were computed by assuming the hydraulic radius of the bed to be equal to the mean water depth (column 5). The unit discharge (column 14) was obtained directly from the author's values which were originally computed from the measured discharge through the central portion of the flume.

Although not included in this summary, the author's data also recorded the mean diameter and Kramer's uniformity modulus for the material transported during each run.

EXPERIMENTS AT THE UNITED STATES WATERWAYS EXPERIMENT STATION ON SANDS NOS. 1 to 9

The United States Waterways Experiment Station has published data (36) obtained from a series of flume studies on nine different natural sand mixtures. Particular emphasis was given to the study of the rates of movement of bed materials of various sizes, and the tractive forces necessary for the commencement of their movement. Information was also obtained on riffle formations, bed roughness, turbulence, and velocity variations.

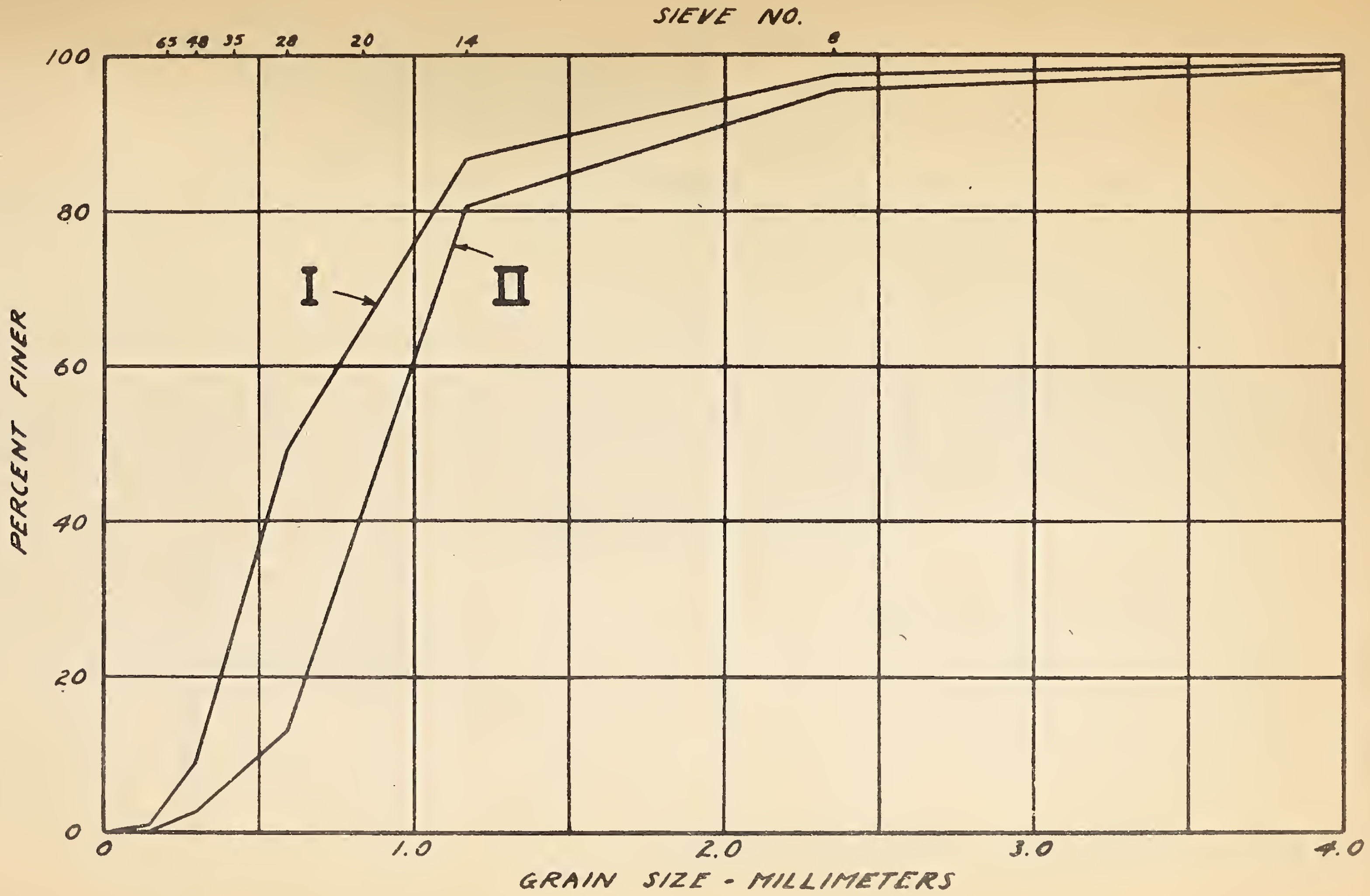
Experimental Equipment and Measurements

All experiments were conducted in a tilting flume approximately 48 feet long, 2.3 feet wide and 1.3 feet deep with walls and bottom of concrete troweled to a smooth surface (fig. 6). Discharge was measured by a V-notch weir, and water surface and bed elevations were measured by a point gage mounted so as to slide along rails on the side of the flume. Sand was introduced during the experiments both manually and by a sand-feed machine.

Materials Tested

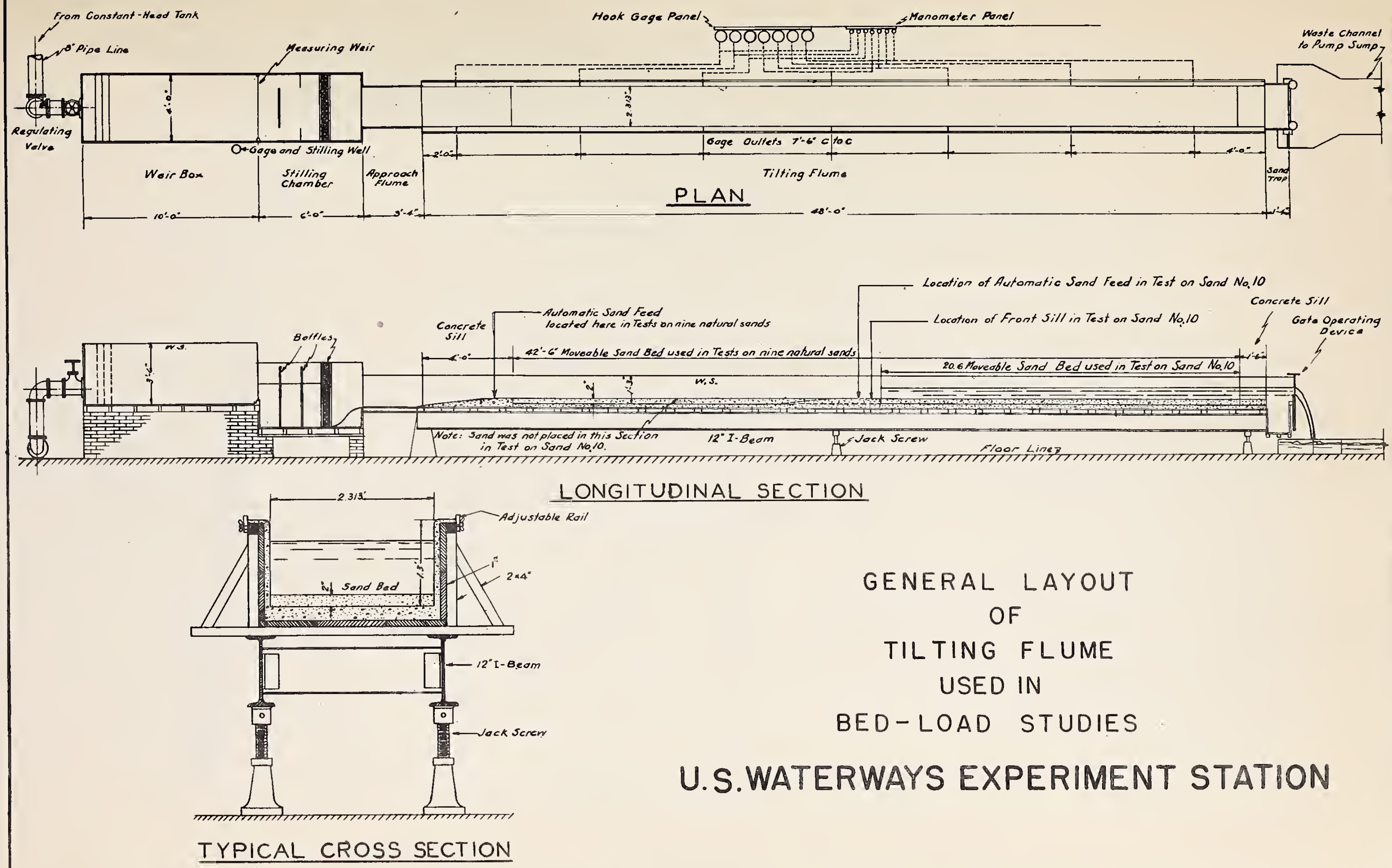
All the materials tested during the course of this study were natural mixtures, found either in the bed of the Mississippi River, or in deposits near Vicksburg, Miss. (items 17-25, table 1). The materials were composed of quartz and feldspar particles, with minute quantities of other minerals,

Figure 5



MATERIALS TESTED BY JORISSEN

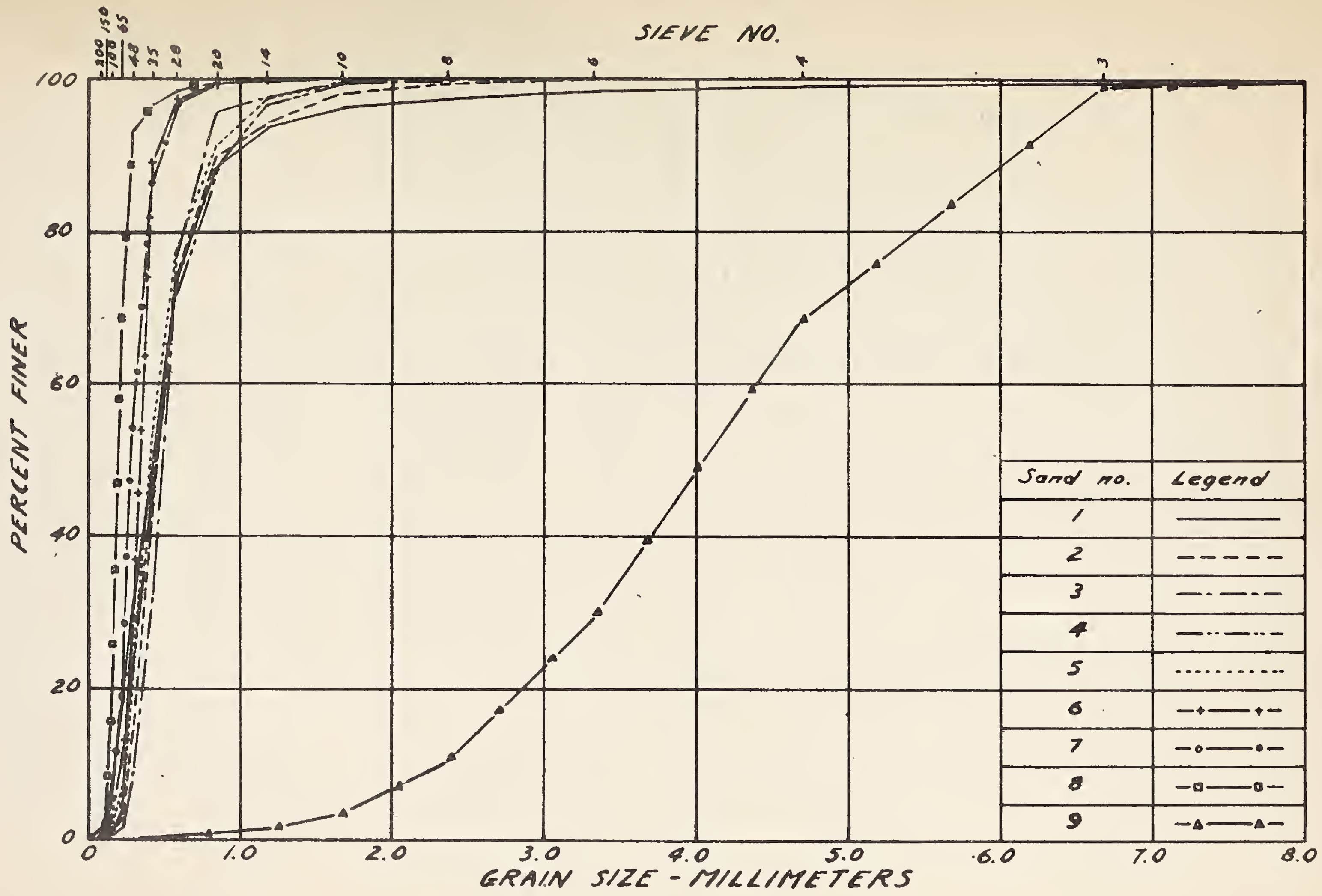
Figure 6



GENERAL LAYOUT
OF
TILTING FLUME
USED IN
BED-LOAD STUDIES

U.S. WATERWAYS EXPERIMENT STATION

Figure 7



U.S.W.E.S. SANDS NOS. 1-9

the shape of the particles ranging mostly from sub-angular to sub-rounded with some angular and some rounded particles. Figure 7 shows the mechanical analysis curves of the 9 mixtures tested, and their physical properties are summarized in table 6.

Table 6.—Summary of physical properties of sands Nos. 1 to 9, tested at the United States Waterways Experiment Station

Sand No.	Specific gravity	Size limits	Diameter		Phi standard deviation	Uniformity modulus
			Mean	Phi arithmetic mean		
		Millimeters	Millimeters			
1....	2.65	0.074-9.423	0.586	+1.35	0.92	0.280
2....	2.65	.147-3.327	.541	+1.10	.61	.439
3....	2.65	.147-2.362	.525	+1.09	.46	.539
4....	2.65	.074-2.362	.506	+1.21	.77	.406
5....	2.65	.104-1.651	.483	+1.21	.69	.438
6....	2.65	.147-0.833	.347	+1.61	.52	.643
7....	2.65	.074-0.833	.310	+1.83	.52	.525
8....	2.65	.074-0.833	.205	+2.43	.37	.560
9....	2.65	.295-6.680	4.077	-1.95	.51	.566

Experimental Procedure

The flume was adjusted to a desired slope by means of screw jacks, and the bed material molded to this exact slope by means of a template mounted on a frame constructed to slide along the rails on the flume. For a particular discharge the tail gate was manipulated as often as was necessary to maintain the slope of the water surface parallel to the original slope. When bed movement became appreciable, the sand discharge was determined during a measured time interval. Sand was introduced both manually and by a sand-feed machine, the intention being to maintain the rate of feeding the same as the rate at which sand was being caught in the trap.

For a particular slope the discharge was increased in successive small increments, until the maximum capacity of the supply pipe was reached. After the conclusion of a series of runs, the flume was set to another slope, the bed was remolded to that slope, and another independent series of runs was made in a similar manner. In general, no data were recorded for a run until an absolute equilibrium had been reached.

Data Appearing in Summary

With the exception of those runs in which no sand movement was recorded, all data appearing in tables 11 to 37, inclusive, of the original paper were used in preparing the summary presented in table 31.

In reducing the original data to that appearing in the following tables the same procedure as outlined in the sample calculation on pages 5 to 7 was followed.

EXPERIMENTS AT THE UNITED STATES WATERWAYS EXPERIMENT STATION ON SAND NO. 10

The United States Waterways Experiment Station (45) has made a series of flume tests of a synthetic sand mixture, which is a continuation of the study described in its Paper No. 17.

Experimental Equipment and Measurements

This series of tests was conducted in the same concrete tilting flume (see fig. 6 and description on p.18), used in the tests described in Paper No. 17.

Materials Tested

The synthetic sand mixture (item 26, table 1) studied in these tests was prepared by mixing together uniform sieve sizes of Fitler sand (sand No. 5, Paper 17) previously screened from a natural mixture of the material. The material was composed primarily of quartz and feldspar particles, and the shapes of the particles ranged from sub-angular to angular. Figure 8 shows the mechanical analysis curve of this mixture, and table 7 summarizes its physical properties.

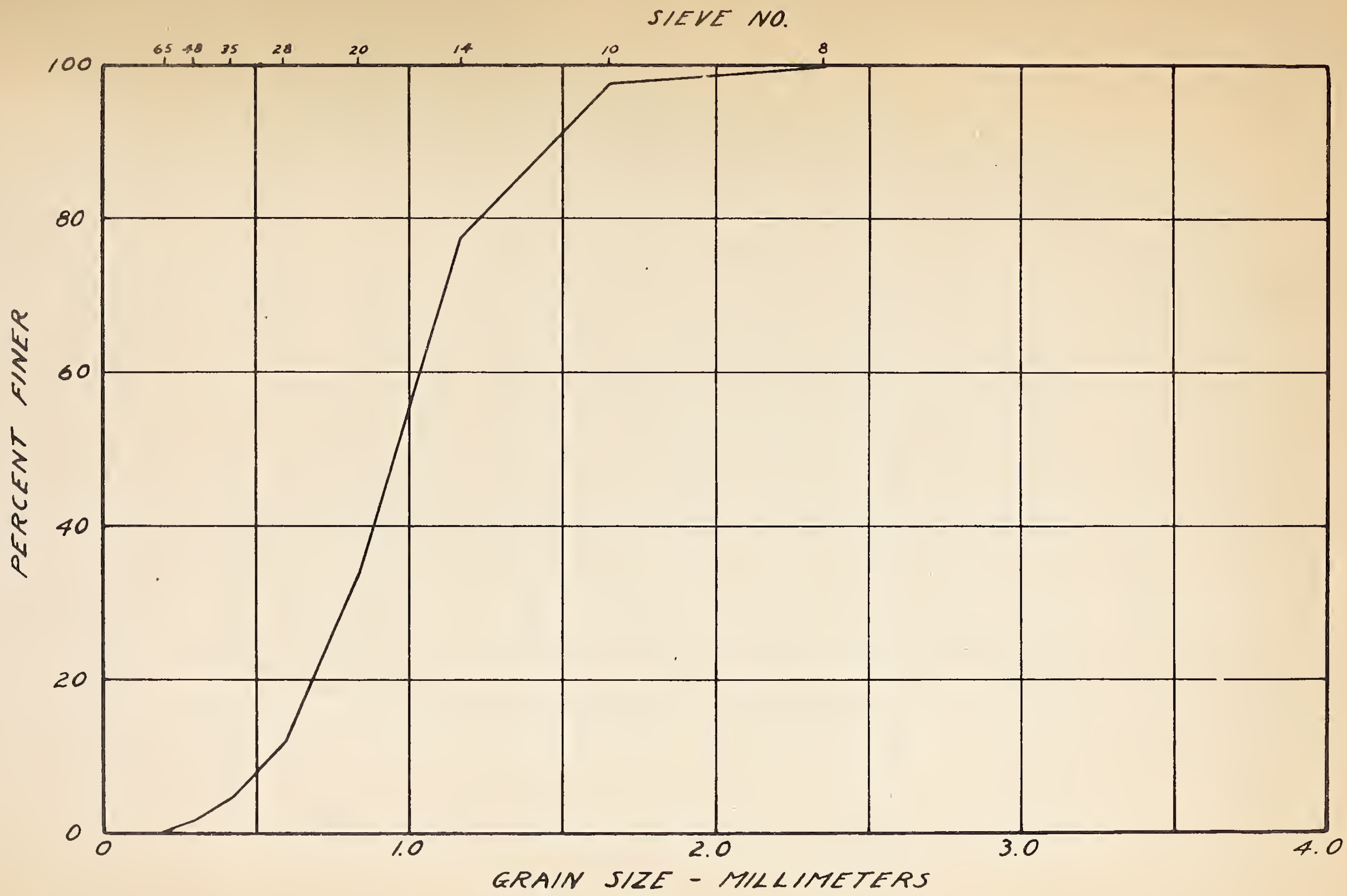
Table 7.—Summary of physical properties of sand No. 10 tested at the United States Waterways Experiment Station

Sand No.	Specific gravity	Size limits	Diameter: Mean	Diameter: Phi arithmetic mean	Phi standard deviation	Uniformity modulus
		Millimeters	Millimeters			
10...	2.65	0.208–2.362	0.976	+0.14	0.48	0.564

Experimental Procedure

The procedure was practically the same as that used with the 9 natural sand mixtures of Paper 17. The length of the movable bed section used in the flume tests with sand No. 10 was only 20.6 feet as compared with 42.5 feet in the tests on the natural sands. The tests proper were conducted in exactly the same manner as those of Paper No. 17 (see p. 19). They were carried further, however, in that they were first carried through a series of rising stages, then through a series of falling stages, and were not terminated when the maximum discharge of the supply pipe had been reached.

Figure 8



U.S.W.E.S. SAND NO. 10

Data Appearing in Summary

With the exception of those runs in which no sand movement was recorded, all the data appearing in tables 5 to 10, inclusive, of the original memorandum were used in preparing the summary presented in table 32. In reducing the original data to that appearing in table 32 the same procedure as outlined in the sample calculation on pages 5 to 7 was followed.

EXPERIMENTS AT THE UNITED STATES WATERWAYS EXPERIMENT STATION ON THE EFFECT OF TURBIDITY ON SAND MOVEMENT

The purpose of these experiments (43) was to determine the maximum turbidity at which water could be used in movable-bed models without effecting the results.

Experimental Equipment and Measurements

A glass-sided flume 1 foot wide, 2 feet deep, and 25 feet long, in which sand was molded to a depth of 0.3 foot, was used. Sills at the upstream and downstream ends of the flume prevented the sand from sloughing off and provided a smooth transition section between the stilling chamber and the flume proper (fig. 9). A more detailed description of this flume has been published by C. E. Bentzel and J. B. Tiffany (3).

Materials Tested

The physical properties of the sand used in these tests (item 27, table 1) are summarized in table 8. The mechanical analysis curve of the mixture is shown in figure 10.

Table 8.--Summary of physical properties of sand used in turbidity tests at the United States Waterways Experiment Station

Material	Specific gravity	Size Limits	Diameter		Phi standard deviation	Uniformity modulus
			Mean	Phi arithmetic mean		
		Millimeters	Millimeters			
Turbidity test...	2.65	0.074-2.362	0.647	+0.88	0.89	0.345

Experimental Procedure

Tests were made with depths of 0.2 and 0.5 foot with the slope of the flume maintained at a value of 0.0010. In order to provide base tests with zero turbidity, two tests (Nos. 1 and 2) were conducted using clear water in the system. In these tests the discharge and the tail-gate settings necessary to maintain the 0.2 and 0.5 foot depths at the slope of 0.0010 were determined. In all the tests that followed, the discharges and tail-gate settings were kept the same as in the base tests, the water-surface slope being permitted to adjust itself to the prevailing turbidity conditions and bed configuration.

After completion of the two base tests, the clear water was drained from the sump and replaced by water of relatively low turbidity. Tests at the two depths were made with this water, after which the turbidity was increased in steps by the addition of silt to the water until a maximum turbidity at about 1,100 parts per million was reached. After each increase in turbidity the 0.5 foot depth was tested first, but only after the flume had been flooded and allowed to stand quietly for one hour before commencement of the test. With depths of 0.2 foot no settlement period was provided. Before tests 17 to 20, inclusive, the flume was flooded and allowed to stand quietly for approximately 16 hours before commencing operation.

Data Appearing in Summary

All the data appearing in table 1 of the original report have been used in preparing the summary presented in table 33. It will be noted that an additional column (column 15a) has been included to give a record of the turbidity.

In reducing the original data to that appearing in table 33, the same procedure, as outlined in the sample calculation on pages 5 to 7, was followed. In computing the hydraulic radius of the bed (column 10) Manning's n of the glass sidewalls was assumed to have the value 0.0080.

UNITED STATES WATERWAYS EXPERIMENT STATION EXPERIMENTS ON SYNTHETIC MIXTURES

The United States Waterways Experiment Station (47) has made a series of flume tests for the purpose of developing a synthetic sand mixture which would move without the formation of riffles in the ranges of depth and slopes usually encountered in movable-bed models.

Experimental Equipment and Measurement

All of the tests were conducted in the glass-walled tilting flume shown in figure 9 and described on page 21.

Materials Tested

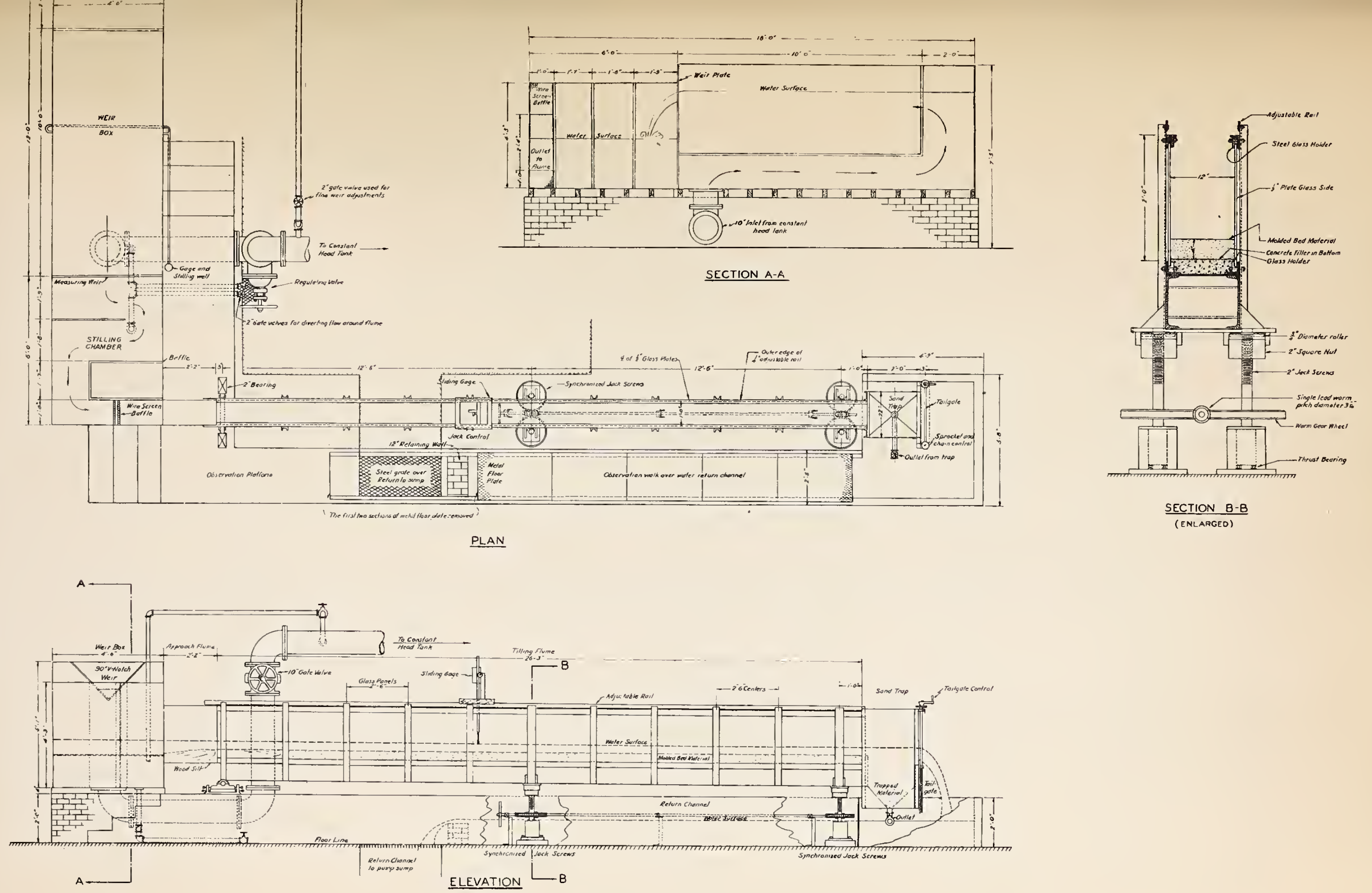
Thirteen synthetic sand mixtures, four sands of uniform size, and one natural sand mixture were tested (items 28-45, table 1).

The natural sand mixture commonly designated as "Fitler" sand was obtained from the Pearl River, near Jackson, Miss. This material was composed primarily of quartz and feldspar particles.

The uniform grain size sands were obtained by screening "Fitler" sand with a set of standard sieves. The 13 synthetic sand mixtures were prepared by mixing varying proportions of the uniform size sands.

The physical properties of the various materials are summarized in table 9, and their mechanical analysis curves are shown in figure 11.

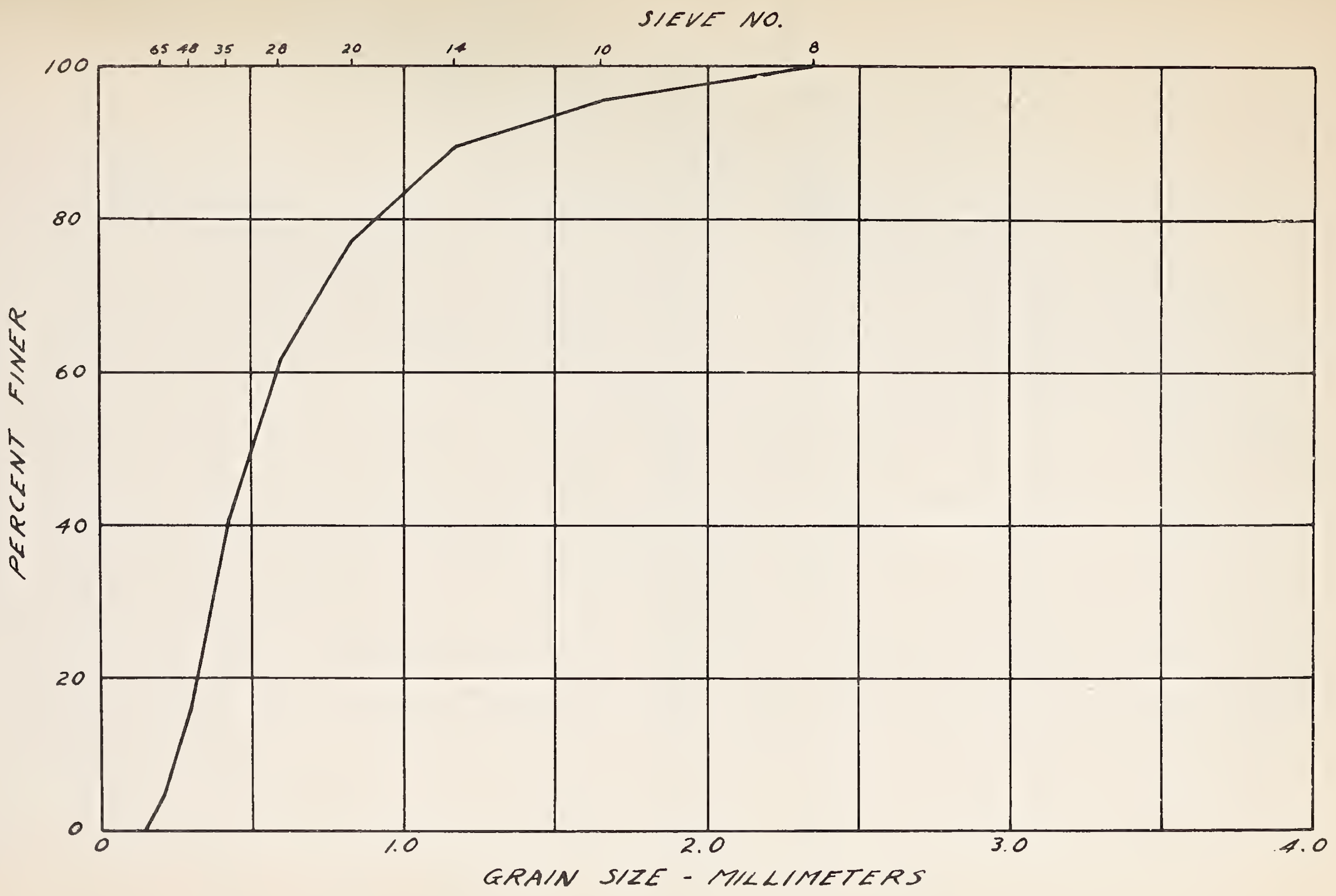
Figure 9



GENERAL LAYOUT OF GLASS TILTING FLUME

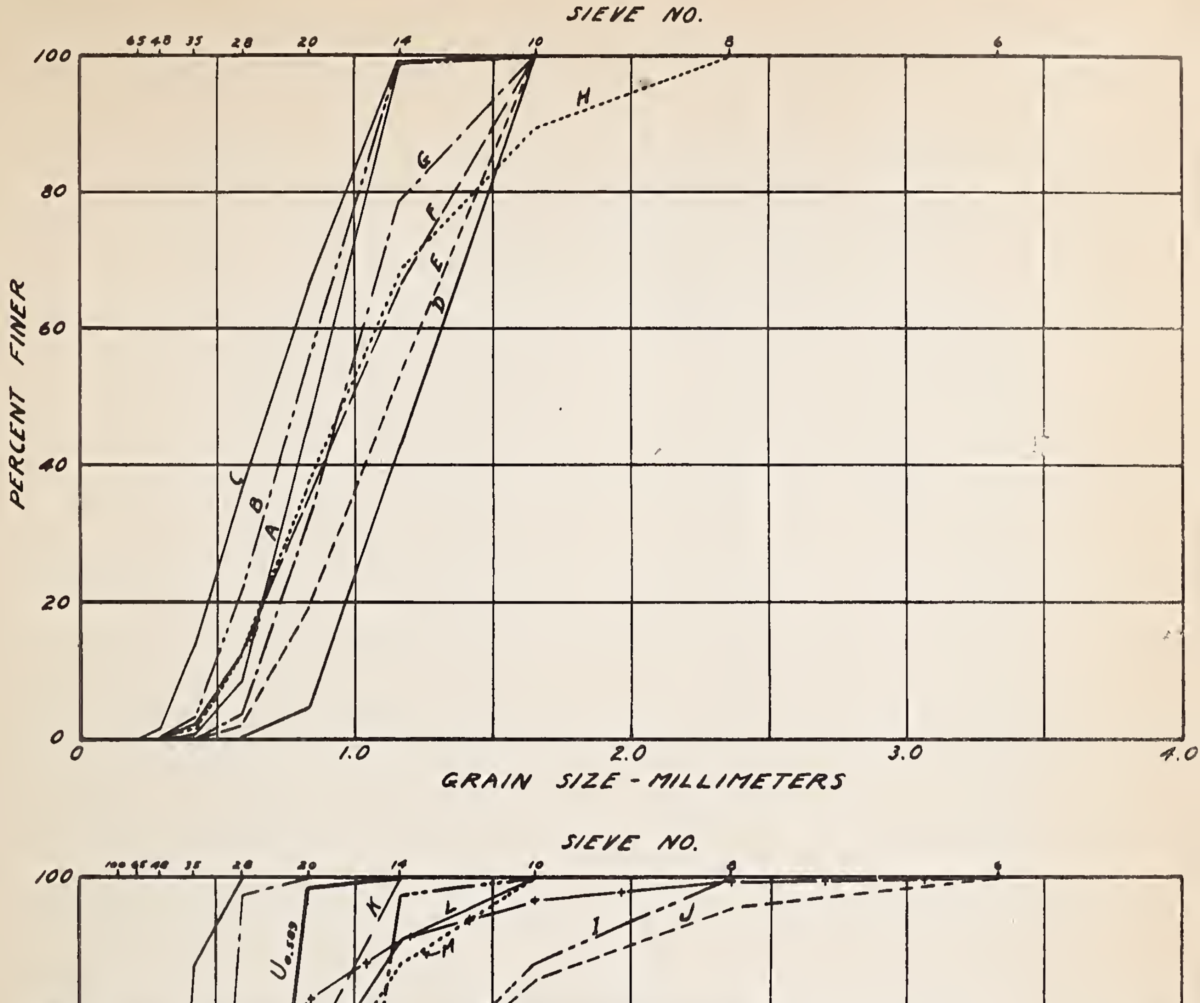
U. S. WATERWAYS EXPERIMENT STATION

Figure 10



SAND USED IN U.S.W.E.S. TURBIDITY TESTS

Figure 11



U.S.W.E.S. SYNTHETIC MIXTURES

Table 9.—Summary of physical properties of synthetic mixtures tested at the United States Waterways Experiment Station

Sand No.	Specific gravity	Size limits	Mean diameter	Uniformity modulus
		Millimeters	Millimeters	
A.	2.65	0.417-1.168	0.853	0.666
B.	2.65	.295-1.168	.794	.603
C.	2.65	.295-1.168	.715	.536
D.	2.65	.589-1.651	1.224	.689
E.	2.65	.417-1.651	1.162	.636
F.	2.65	.417-1.651	1.008	.546
G.	2.65	.417-1.651	.986	.628
H.	2.65	.417-2.362	1.067	.496
I.	2.65	.295-2.362	1.052	.461
J.	2.65	.295-3.327	1.066	.424
K.	2.65	.295-1.168	.732	.636
L.	2.65	.208-1.651	.738	.503
M.	2.65	.208-1.651	.759	.475
U (0.295).	2.65	.208-0.589	.367	.752
U (0.417).	2.65	.295-0.833	.498	.791
U (0.589).	2.65	.417-1.168	.691	.774
U (0.833).	2.65	.589-1.651	.976	.786
Fitler.	2.65	.147-3.327	.597	.369

Experimental Procedure

Each material was tested at three depths of flow, 0.25, 0.50, and 0.75 foot, and each designated as a separate test. Within each test, 5 or more similar runs at 30 minutes duration each were made. A constant slope of 0.0010 was used in all tests. The bed was molded flat at the beginning of each test.

The preparation and placement of materials in the flume, setting the slope of the flume, and molding the bed, were done in exactly the same manner described in Paper 17. In all tests, particularly in those at 0.5 foot and 0.75 foot depths, the discharge and slope were maintained at constant values and the depth of flow during each run was allowed to increase as the roughness of the bed increased due to riffle or wave formations. Once the weir discharge had been satisfactorily adjusted for the first run of a test, it was not changed for any of the succeeding runs. Although an attempt was made to make the tail-gate setting constant for all runs of the test, it was found that slight adjustment had to be made, due to changes in bed roughness, to keep the water-surface slope constant.

Data Appearing in Summary

Those data appearing in tables 7 to 23, inclusive, of the original report have been used in preparing the summary presented in table 34. In all, 21 series of tests were conducted—1 on the natural mixture, 4 on uniform sand sizes, and 16 on synthetic mixtures. Of the 16 tests on the synthetic mixtures, 3 were repeat experiments conducted for check purposes.

In reducing the original data to that appearing in the following tables, the same procedure as outlined in the sample calculations on pages 5 to 7 was followed. In computing the hydraulic radius of the bed (column 10) Manning's n of the sidewalls was assumed to be 0.0080.

UNITED STATES WATERWAYS EXPERIMENT STATION, EXPERIMENTS ON THE CRITICAL TRACTIVE FORCE OF COARSE MATERIAL

These experiments (44) were made to determine the minimum tractive force required to keep individual particles of sand and gravel in motion, after they had been dropped from the surface of a flowing stream.

Experimental Equipment and Measurements

The tests were conducted in the glass-walled tilting flume shown in figure 9 and described on page 21. The bottom of the flume was covered with a layer of compacted sand, which in turn was overlaid with a thin surface of cement grout, roughened to approximately the resistance to flow offered by a molded sand bed. The slope of the water surface was maintained in each test at the same slope to which the flume had been set, and was checked by measurements from a needle gage, which was so mounted as to slide along the side rails on the top of the flume.

Materials Tested

Twelve sizes of material (items 46-57, table 1) were used in these tests. All the materials were sub-rounded, and were composed mostly of chert and quartz of the specific gravity of about 2.65. The physical properties of the 12 sizes of material are summarized in table 10.

Table 10.—Summary of physical properties of coarse materials used in critical tractive-force studies at the United States Waterways Experiment Station

Material No.	Specific gravity	Mean diameter
		Millimeters
U (.056)	2.65	1.42
U (.079)	2.65	2.01
U (.112)	2.65	2.84
U (.158)	2.65	4.01
U (.224)	2.65	5.69
U (.317)	2.65	8.05
U (.448)	2.65	11.4
U (.65)	2.65	16.5
U (.96)	2.65	24.4
U (1.55)	2.65	39.4
U (1.95)	2.65	49.5
U (2.30)	2.65	58.4

Experimental Procedure

The tests on critical tractive force consisted of 4 independent tests conducted at 4 different slopes. The flume itself was first set to a desired slope, and the water surface maintained at the same slope for all depths. The first run was made at a depth of about 0.05 foot, after which the depth was increased by small increments to about 0.75 foot.

During the first run, several particles of the 1.42 mm size were dropped into the water from the surface and carefully watched. It was found that they would all come to rest with almost no downstream movement after once having reached the bottom. After several runs, it was found that a few of the grains would proceed downstream in an unsteady manner, and as the depth was further increased, more and more of the particles would move steadily. When it was found that practically all the grains of this size were carried steadily downstream with only infrequent short pauses, the critical tractive force for that size was said to have been reached.

As that test continued with increasing depths, the critical tractive forces of the successively larger sized grains were determined in the same manner. The pebbles were pushed very gently off a sheet-metal pan which was held horizontally exactly at the surface of the water, in such a manner that they were not given any initial velocity in either a downstream or a vertical direction.

After the completion of the test at the first slope (0.0005), the slope of the flume was changed, and successive tests were run at slopes of 0.0010, 0.0015, and 0.0020. The procedure in each test was exactly the same as that described above.

In addition to the critical tractive-force tests, a series of tests were conducted to determine the downstream drift of particles. The experimental technique in these latter tests varied only slightly from the technique used in the test described above. The test was started with a very small discharge, which was increased in small increments until a depth of about 1.5 feet had been reached, the slope of the water surface being maintained at all times parallel to the slope of the flume bed (0.00045). At each depth of flow, samples of each size of grain were dropped from the water surface, and the horizontal distance between the points, where the grains entered the water, and the point where they struck the bottom, was recorded.

Data Appearing in Summary

Since the tests give no information on either the rate of bed-load transportation or bed roughness, the various experimental data have not been summarized.

UNITED STATES WATERWAYS EXPERIMENT STATION STUDIES ON THE MOVEMENT OF LIGHT-WEIGHT MATERIALS

This investigation (46), consisting of two parts, contains the results of a study of a great number of light-weight materials suggested for use as model bed material. The first part contains a discussion of the properties of various light-weight materials that tend to make them suitable or unsuitable for use as model bed material. The second part contains the results of a series of flume tests, conducted with those materials that were recommended in the first part as being suitable for general use as model bed material. For a preliminary analysis of some of these data, the reader is referred to the paper of O. G. Haywood (40).

Experimental Equipment and Measurements

The tests were conducted in the glass-walled tilting flume shown in figure 9 and described on page 21.

Materials Tested

From an investigation of the properties of 60 materials from a wide range of sources, only Haydite, coal, rosin, and Gilsonite were recommended as being practical for use as model bed material (items 58-76, table 1). The recommendations were based on an investigation of the properties and cost of the materials. Table 11 summarizes the physical properties of the various materials and mixtures tested. Mechanical analysis curves of the materials before testing are shown in figure 12.

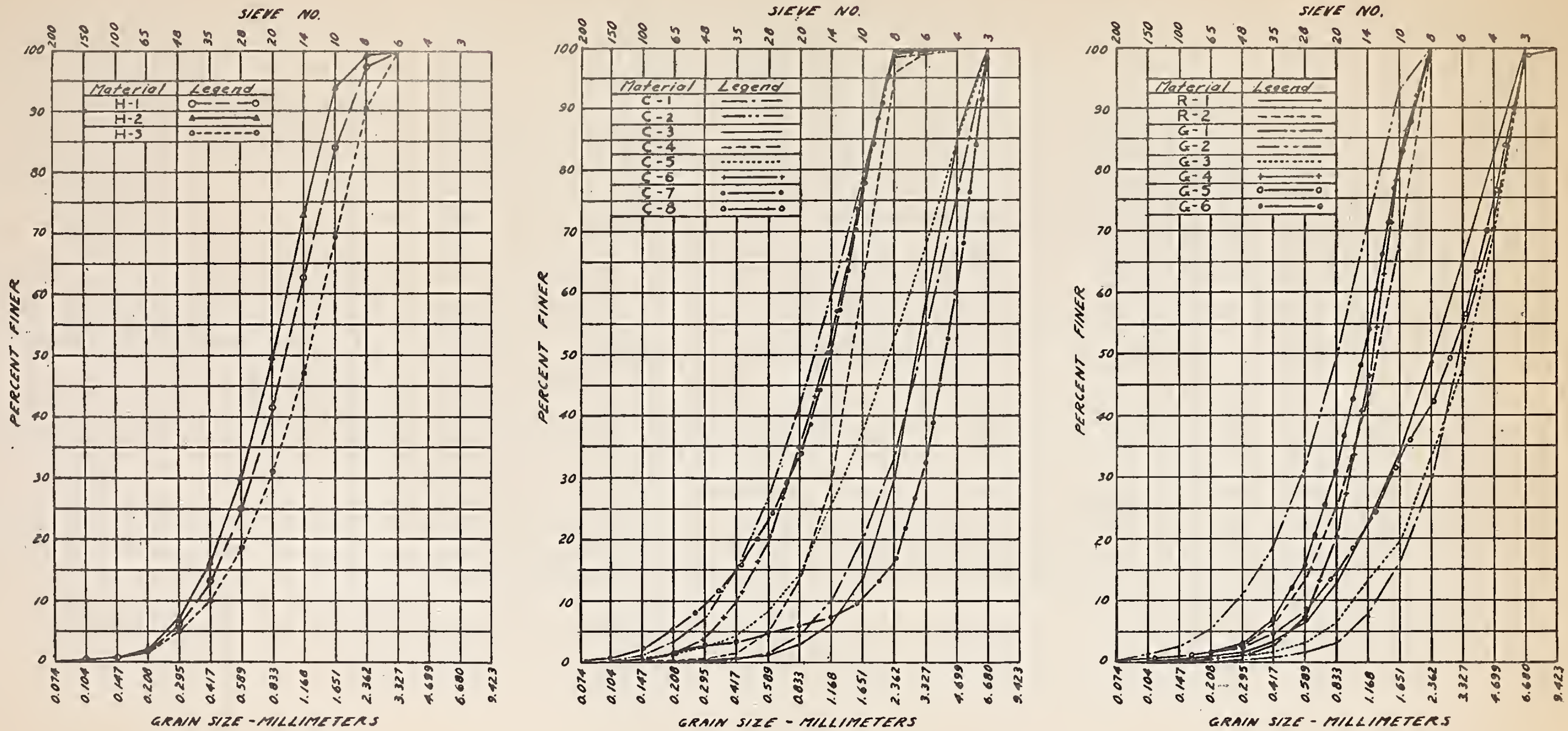
Experimental Procedure

The method of operation, which includes preparation and placement of materials in the flume, setting the slope of the flume, molding the bed, and the actual test, was essentially the same as that described in Paper 17. Porous materials, however, were soaked and stirred until they reached their maximum specific gravity before placement. Material was fed manually into the flume at a rate about equal to that deposited in the trap.

Data Appearing in Summary

With the exception of those runs in which no sand movement was recorded, all the data appearing in tables 15 to 54, inclusive, of the original memorandum were used in preparing the summary presented in table 35. In reducing the original data to that appearing in table 35 the same procedure as outlined in the sample calculation on pages 5 to 7 was followed. In computing the hydraulic radius of the bed (column 10) Manning's n of the sidewalls was assumed to be 0.0080.

Figure 12



U.S.W.E.S. LIGHT-WEIGHT MATERIALS

Table 11.--Summary of physical properties of various light-weight materials at the United States Waterways Experiment Station

	Material	Specific gravity*	Mean grain Milli-meters	Uniformity modulus	Shape of grains	Color	General description
H-1	Haydite No.6 (H.Co.)	1.85	1.067	0.378	Angular	Gray	Hard, porous and cellular in structure. A clay or shale burned under patented process.
H-2	Haydite, 1/8-in. (H.Co.)	1.35	.908	.401			
H-3	Haydite (H.-P.B.Co.)	1.74	1.329	.365			
C-1	Corona coal - Alabama	1.349	3.300	.399	Angular	Black	Amorphous, brittle, and porous. Pure bituminous coal.
C-2			1.097	.341			
C-3	Slack coal - Illinois	1.316	3.197	.466	Angular	Black	Amorphous, brittle, and porous. Bituminous coal containing 14.4 percent impurities consisting chiefly of quartz and calcareous materials.
C-4			1.485	.518			
C-5	Semi-Anthracite Coal Briquettes	1.308	2.610	.287	Angular	Black	Amorphous, brittle, and porous, Seventy percent anthracite and 30 percent semi-anthracite coal dust compressed with a binder of 6 percent petroleum asphalt.
C-5			1.168	.397			
C-7	Flake Pitch	1.259	3.963	.485	Angular	Black	Amorphous; hard, brittle, and porous. Residue left from the destructive distillation of coal tar.
C-8			1.147	.372			
R-1	Helix 1 Limed (Wood) Resin	1.111	2.777	.305	Angular	Light yellow	Impervious, subtranslucent, brittle, and amorphous.
R-2			1.317	.440			
G-1	Gilsonite (Brilliant Black-seconds)	1.070	3.553	.398	Angular	Black	Amorphous, very hard, and porous, a natural product of the earth, an asphalt common in Utah.
G-2			.899	.372			
G-3	Gilsonite (Brilliant Black selects)	1.052	3.526	.366			
G-4			1.249	.524			
G-5	Gilsonite (Regular Run Premium selects)	1.027	3.112	.286			
G-6			1.165	.441			

*Maximum specific gravity that material reaches with soaking and stirring in water.

EXPERIMENTS BY CHITTY HO AND YUN-CHENG TU

The primary purpose of these experiments (23) which were made at the University of Iowa Institute of Hydraulic Research, was the determination of the competent bottom velocity for materials of various sizes and specific gravity.

Experimental Equipment and Measurements

The tests were conducted in a glass-walled flume 30 1/2 inches wide, 3 feet high, and 39 feet long (fig. 13). A false floor approximately 16 feet long was constructed with 6-inch planks laid crosswise of the flume. A sand pit with its upstream edge about 10 feet from the upper end of the false floor, was 2 feet long in Ho's, and 1 foot long in Tu's installation. The depth of the pits could be adjusted to accomodate the samples of sands used in the experiments.

Discharge was measured by a calibrated rectangular suppressed weir. Depths of flow were regulated by a tail gate and measured at the upstream edge of the sand bed by a vernier gage. Velocities were measured by means of either a Pitot tube or a miniature current meter, directly over the sand bed and along vertical lines at the center and quarter points of the channel width.

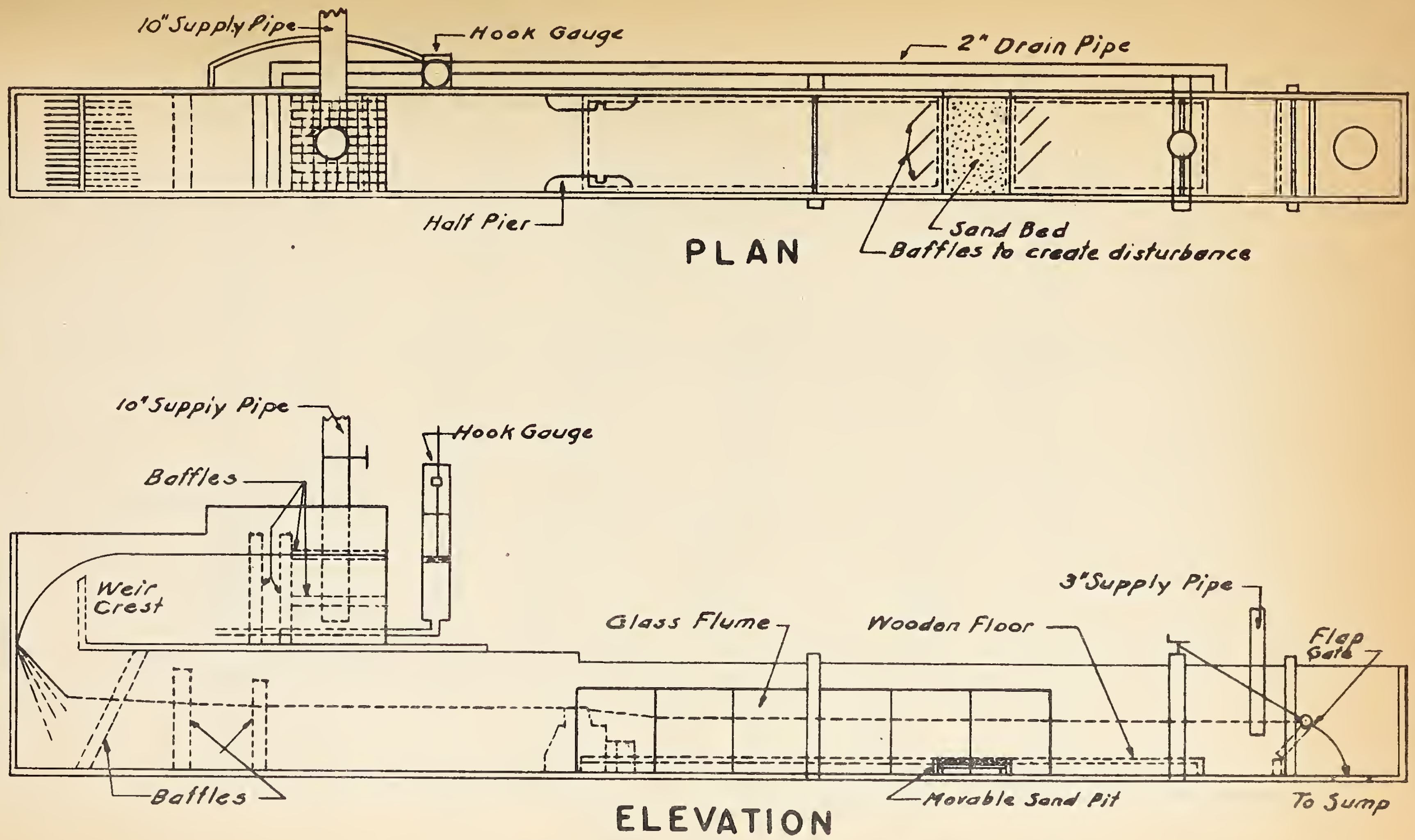
Materials Tested

Four kinds of material (items 77-93, table 1) were used in the investigation (1) Sand from the Iowa River at Iowa City, (2) crushed limestone from a quarry at Iowa City, (3) Haydite obtained from the Haydite Corporation at Kansas City, and (4) a dune sand, known as Knox sand, obtained near North Liberty, Iowa. The first three materials were separated into unigranular sizes by a set of standard sieves, and the sizes shown in table 12 used in the flume tests. The mechanical analysis curves for the unigranular materials are shown in figure 14.

Table 12--Summary of physical properties of materials tested by Ho and Tu

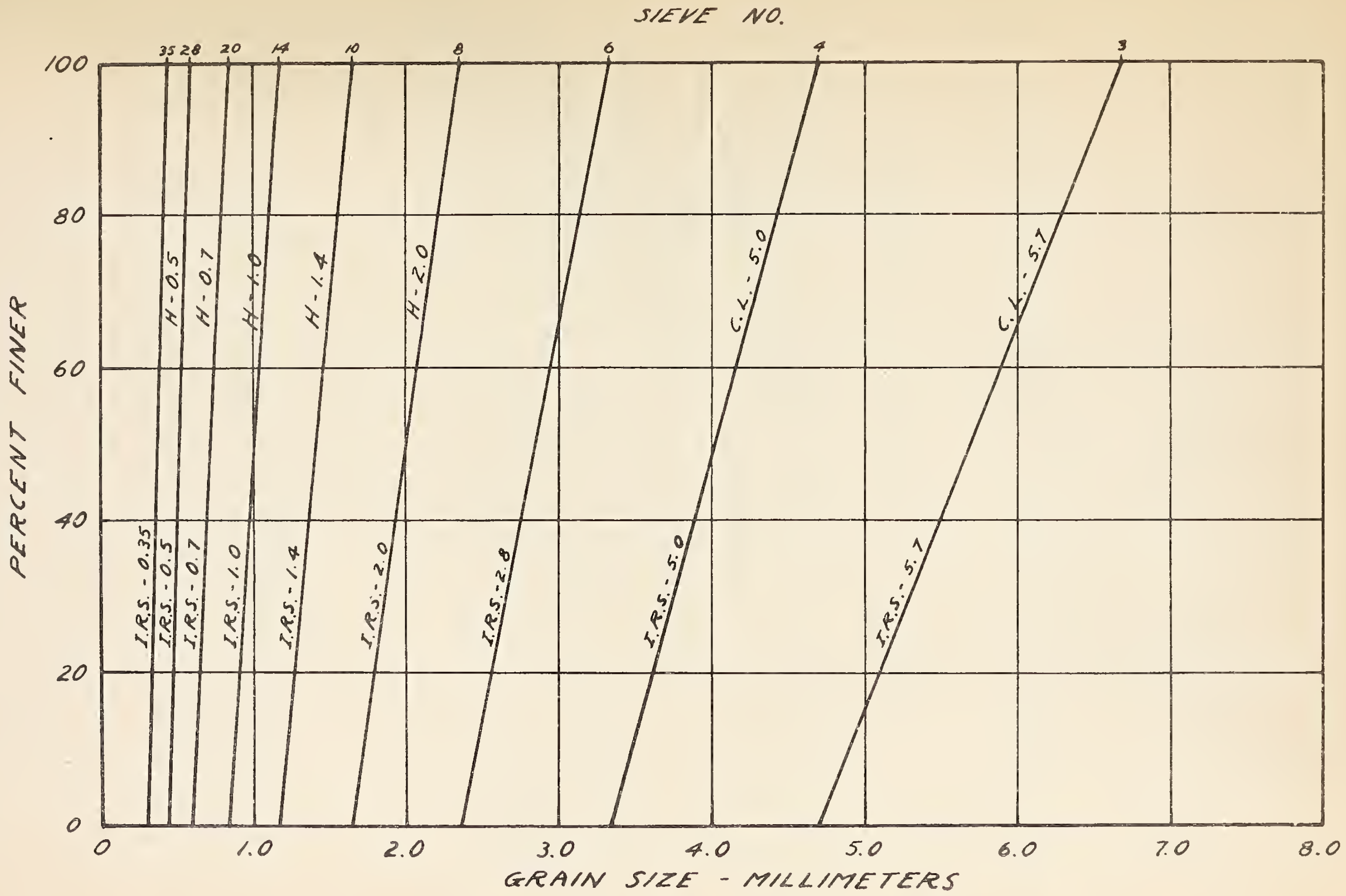
Materials	Specific gravity	Size limits	Diameter of grain	Uniformity modulus
		Millimeters	Millimeters	
Iowa River sand	2.65	4.70-6.68	5.7	0.84
Do	2.65	3.33-4.70	4.0	.84
Do	2.66	2.36-3.33	2.8	.84
Do	2.62	1.65-2.36	2.0	.84
Do	2.63	1.17-1.65	1.4	.84
Do	2.63	.83-1.17	1.0	.84
Do	2.68	.59-0.83	.7	.84
Do	2.62	.42-0.59	.5	.84
Do	2.62	.30-0.42	.35	.84
Crushed limestone	2.66	4.70-6.68	5.7	.84
Do	2.66	3.33-4.70	4.0	.84
Haydite	1.81	1.65-2.36	2.0	.84
Do	1.78	1.17-1.65	1.4	.84
Do	1.83	.83-1.17	1.0	.84
Do	1.88	.59-0.83	.7	.84
Do	1.86	.42-0.59	.5	.84
Knox sand	2.54	.07-0.60	.15	1.68

Figure 13



APPARATUS OF HO AND TU

Figure 14



MATERIALS TESTED BY HO AND TU

Experimental Procedure

Wet material was placed in the sand pit with the surface at the same level as the flume bed. The discharge through the flume was then regulated approximately to a predetermined amount, and, after conditions had become steady, the tail gate was slowly lowered. The bed was watched carefully for the first signs of impending movement. As soon as the particles of sand commenced to roll over the sand bed, the tail gate was locked in position and measurement made of verical velocity curves.

Data Appearing in Summary

Since the tests of Ho and Tu give no information on either bed roughness or the rate of bed-load transportation, the various experimental data have not been summarized.

EXPERIMENTS BY TE YUN LIU AND A. N. CARTER

The objectives of this investigation (42), which was made at the University of Iowa Institute of Hydraulic Research, were to obtain information on the critical bottom velocity for the material tested, as well as the relation between rate of transportation and the size and shape of the particles.

Experimental Equipment and Apparatus

The tests were conducted in a glass-walled flume, 15.5 feet long, 1.01 feet wide, and 2 feet deep (fig. 15). Material to be tested was placed in a pit 1.02 feet long, extending the full width of the flume. Plates in the bottom of the pit could be raised or lowered by adjusting screws, so that the surface of the bed material could be maintained level with the surface at the flume bed. Velocities were measured in a vertical section at the center of the flume by means of a Pitot tube. Depths were measured by a gage clamped on the outside of the flume.

Materials Tested

Two sands and two crushed limestone materials were tested (items 94-97, table 1), the physical properties of which are summarized in table 13. The mechanical analysis curves for the materials are shown in figure 16. The two sands, designated as sand D and sand E, were obtained by sieving Iowa River sand and were well rounded. The two limestone materials, designated materials I and II, were obtained by sieving crushed limestone and most of the grains were sharp edged.

Table 13--Summary of physical properties of materials tested by Liu and Carter

Material	Specific gravity	Size limits	Mean diameter	Uniformity modulus
		Millimeters	Millimeters	
D..............	2.64	2.362-4.699	2.9	0.83
E..............	2.58	0 -2.362	1.4	.74
I..............	2.69	1.168-4.699	2.8	.73
II..............	2.69	3.327-6.680	5.5	.76

Experimental Procedure

Wet material was placed in the pit with the surface at the same level as the flume bed. The discharge was slowly increased, and the tail gate manipulated to hold the depth constant, until the particles on the surface of the bed were just beginning to move. When conditions had become steady, a velocity traverse in a vertical at the center of the flume was observed by means of a Pitot tube.

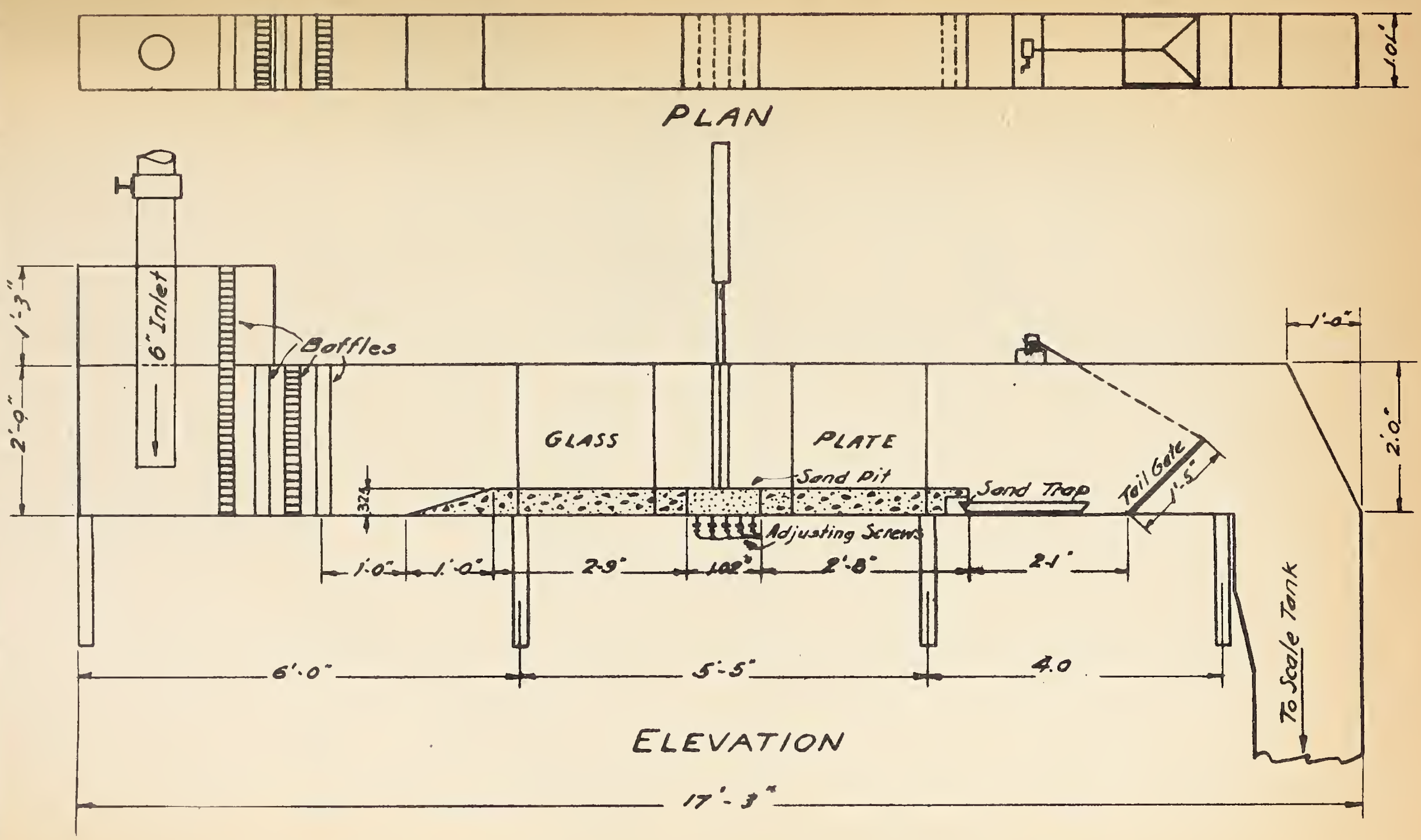
After readings for the competent velocity were obtained, the discharge was increased and the depth kept constant by lowering the tail gate. With steady conditions prevailing at the new discharge, a velocity traverse was again made and the rate of transportation measured. During all of the tests the surface of the bed material in the pit was kept at the same level as the flume bed by frequent adjustment of the adjusting screws.

When testing sands D and E, the velocity traverses were taken with the Pitot tube vertically above the upstream edge of the sand bed, but when testing the limestone material the Pitot tube was placed over the center of the bed.

Data Appearing in Summary

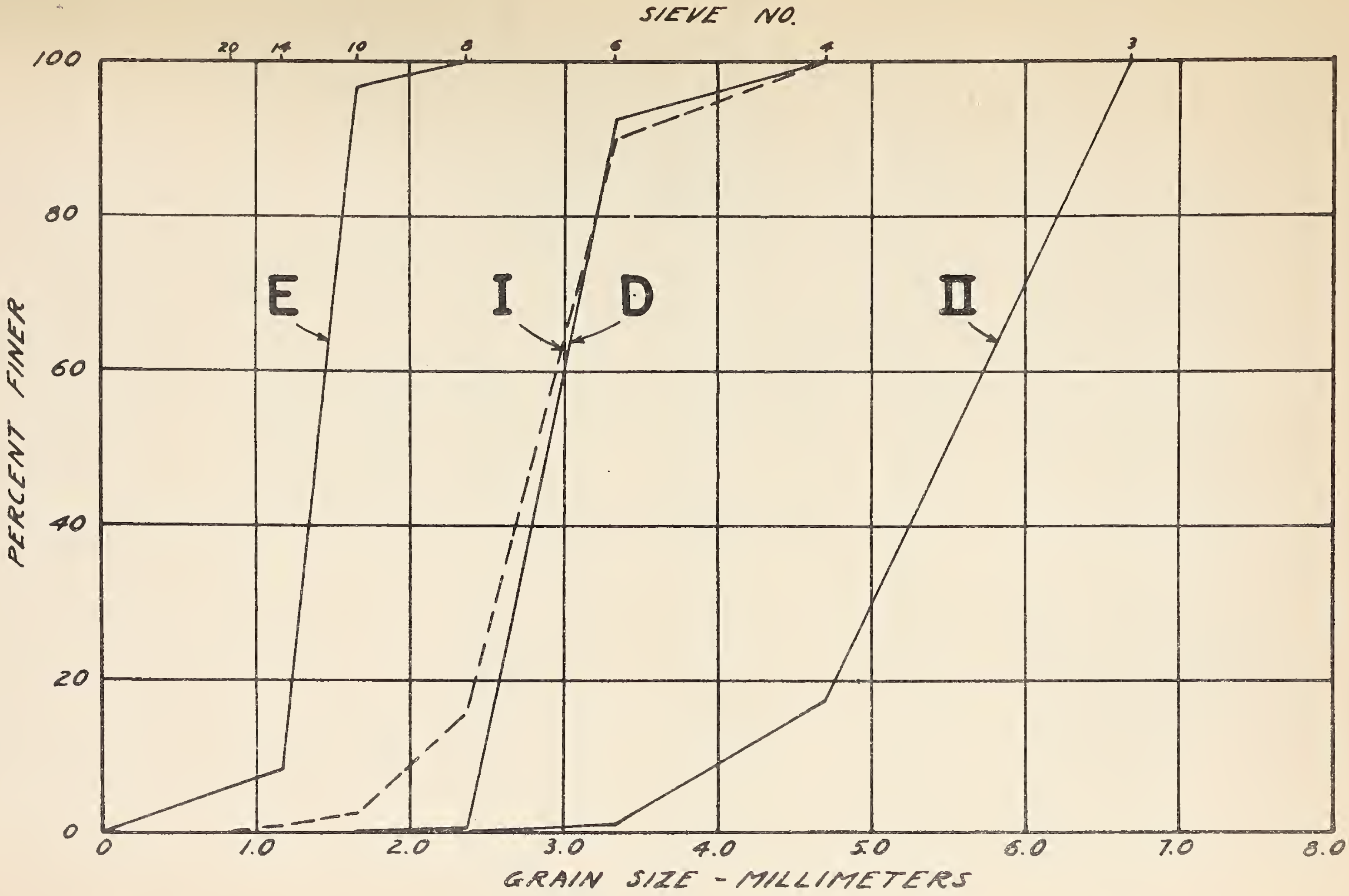
Because non-uniform flow prevailed in the majority of these tests, the results are not comparable to other bed-load investigations. It is also believed that the velocity distributions, as measured, more nearly represented conditions for flow over the concrete bed of the flume upstream from the sand pit rather than flow over a bed of granular material. In view of these various limitations, the basic data from these tests were not considered applicable to the general problem of bed-load transportation and bed roughness. More specifically the data give information on scouring velocities, and hence, are not summarized in this compilation of flume data.

Figure 15



APPARATUS OF LIU AND CARTER
SCALE 1" = 2'

Figure 16



MATERIALS TESTED BY LIU AND CARTER

EXPERIMENTS BY TE-YUN LIU

These experiments (24) were made at the University of Iowa Institute of Hydraulic Research.

Experimental Equipment and Measurements

The tests were conducted in a wooden flume 32 feet long, 32 inches wide, and 16 inches deep, and lined with one-eighth-inch wall board (fig. 17). A false wooden floor 18 feet long, with a recess 9 feet 10 inches long, 2 feet wide, and 2 inches deep for holding materials to be tested, was constructed on the bottom of the flume. A smooth cement mortar approach was constructed at the upper end of the false floor.

Discharge was measured by a calibrated 90° V-notch weir. Elevations of sand and water surface were measured by a point gage mounted to slide on rails fastened to the top of the flume. Velocity distributions were measured during each test by means of a Pitot tube.

Materials Tested

Commercial sand from the Iowa River at Iowa City was screened into 4 grades, designated by the numerals I to IV (items 98-103, table 1). Material V was a mixture of I and II and material VI was a mixture of III and IV. The physical properties of the various mixtures are summarized in table 14, and their mechanical analysis curves are shown in figure 18.

Table 14—Summary of physical properties of materials tested by T. Y. Liu

Mixture	Specific gravity	Size limits	Mean diameter	Uniformity modulus
		Millimeters	Millimeters	
I.............	2.66	2.362-6.680	4.4	0.72
II.............	2.66	2.362-4.699	3.4	.71
III............	2.66	.589-3.327	2.3	.68
IV.............	2.66	.295-2.362	1.4	.67
V...............	2.66	2.362-6.680	3.6	.66
VI.............	2.66	.295-3.327	1.8	.58

Experimental Procedure

With the slope adjusted to a desired value, the material to be tested was thoroughly mixed, placed in the recess in the false floor, and the surface made level with the flume bed. The discharge was started and increased slowly until bed movement started. The depth of the flow was regulated by the tail gate to maintain uniform flow conditions at all times. After data on depths, slope, rates of discharge, and velocity distribution had been recorded for conditions that appeared to be competent, the rate of flow was increased, the tail gate was raised to maintain essentially uniform flow, and the rate of bed-load transportation, in addition to the other factors, was measured.

Early in the testing program it was found that the velocity distribution curves at the upstream end of the sand bed differed materially from those at the downstream end of the bed due to differences in the roughness of the approach and the bed itself. The irregularities in the bed configuration resulting from such conditions were reduced by screens tacked to the smooth floor of the flume.

Data Appearing in Summary

With the exception of those runs in which no sand movement was recorded, all the data appearing in table 4 (pp. 17a-17z) of the original paper were used in preparing the summary presented in table 36.

In reducing the original data to that appearing in table 36, the same procedure as outlined in the sample calculation (pp. 5 to 7) was followed. In computing the hydraulic radius of the bed (column 10) Manning's n of the side walls was assumed to have the value of 0.011. It will be noted that calculations have not been recorded for some of the data in table 17c because the slope measurements as recorded probably were not the slope of the energy gradient and absurd values of bed roughness were obtained.

EXPERIMENTS BY J. BOGARDI AND C. H. YEN

These experiments (38) were made at the University of Iowa Institute of Hydraulic Research.

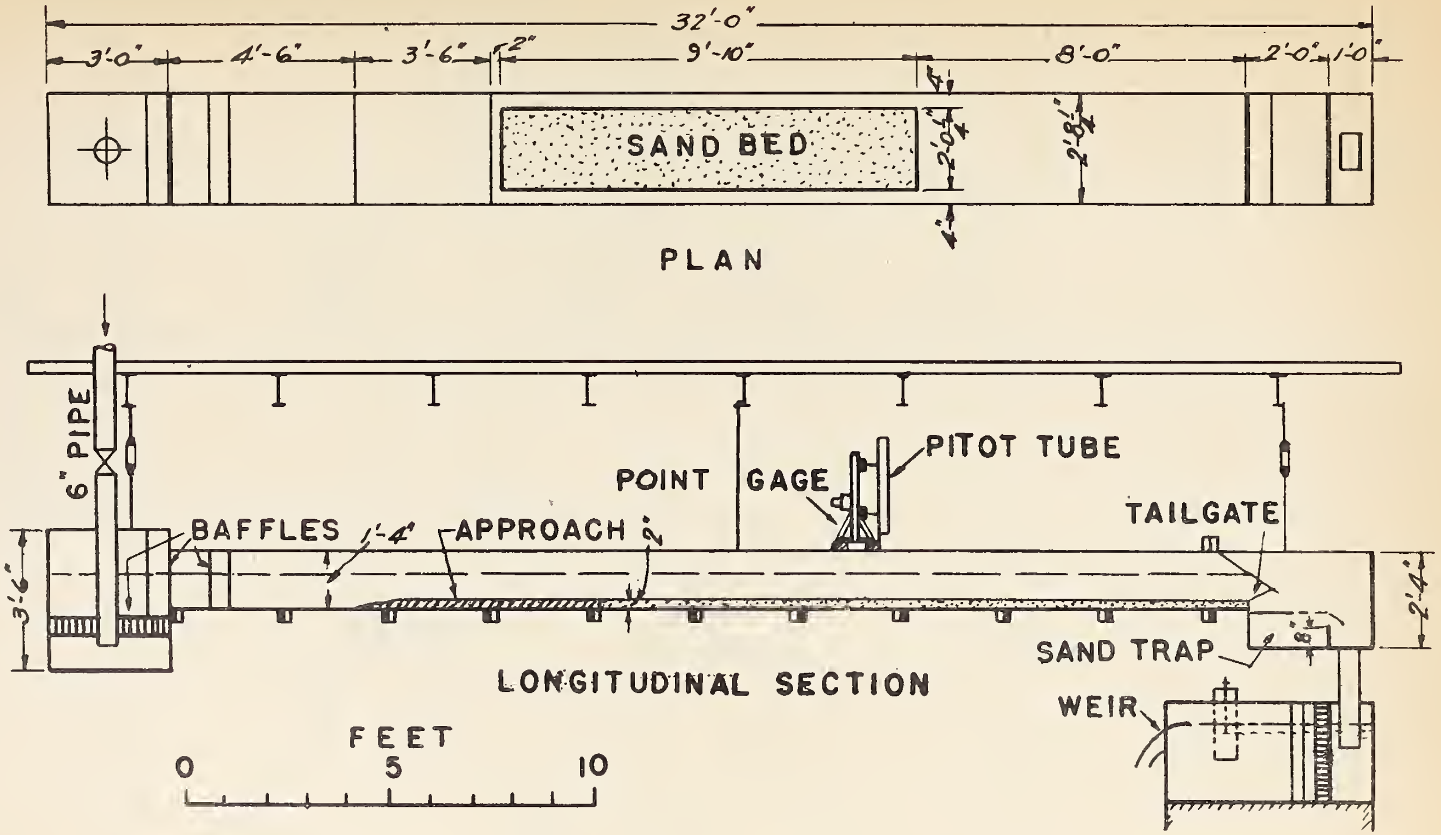
Experimental Equipment and Measurements

The tests were conducted in a wooden flume used previously by Te-Yun Liu (see p. 31). For the first part of the tests the flume was used with the original 33-inch width as shown in the upper part of the figure 19. The flume later was contracted, by means of 2 parallel partition walls, to a width of 12 inches as shown in the lower part of figure 19.

In the wide flume a false wooden floor 19 feet long, with a recess 10 feet long, 2 feet wide, and 3 inches deep for holding materials to be tested, was constructed in the bottom of the flume. In the narrow flume the sand bed covered the total width of the flume.

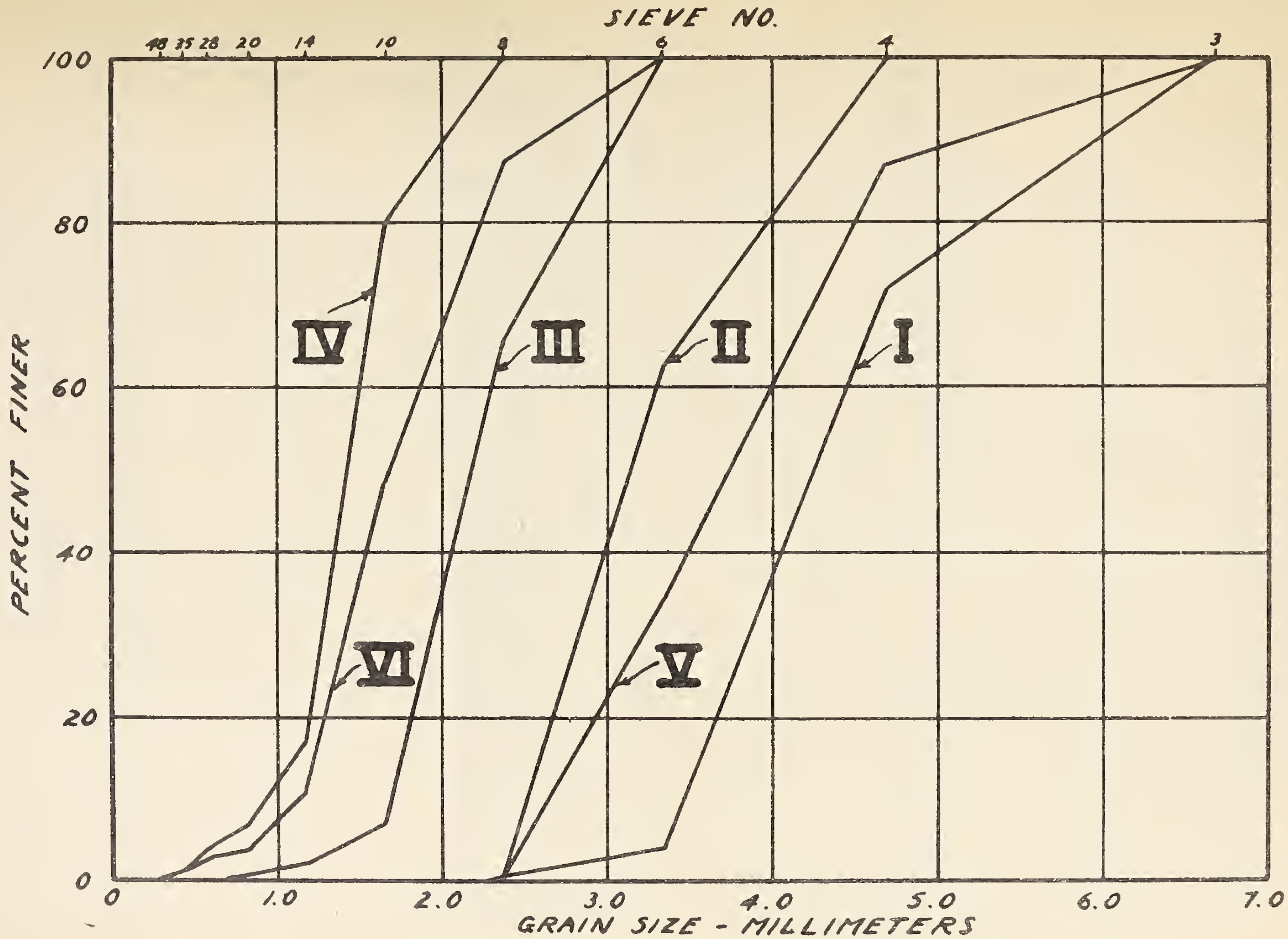
Discharge was measured by a V-notch weir, and velocities were measured by means of a Pitot tube. Elevations of sand and water surface were measured by a point gage mounted on a movable frame.

Figure 17



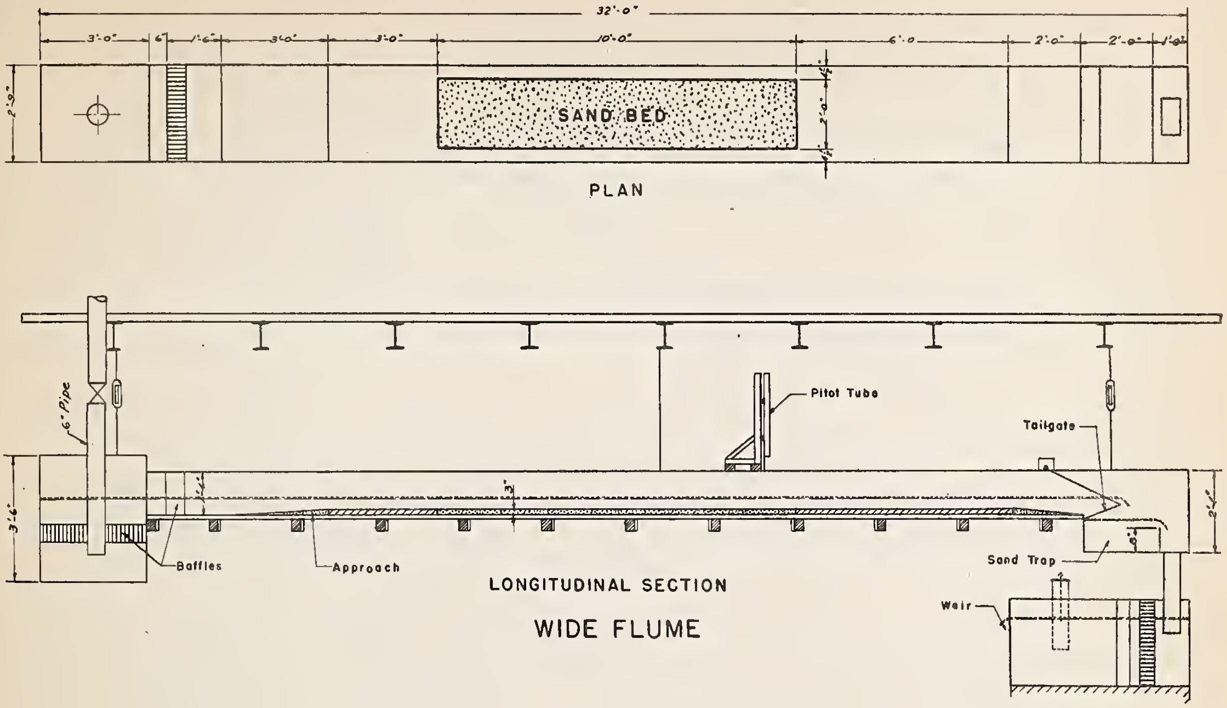
APPARATUS OF T. Y. LIU

Figure 18



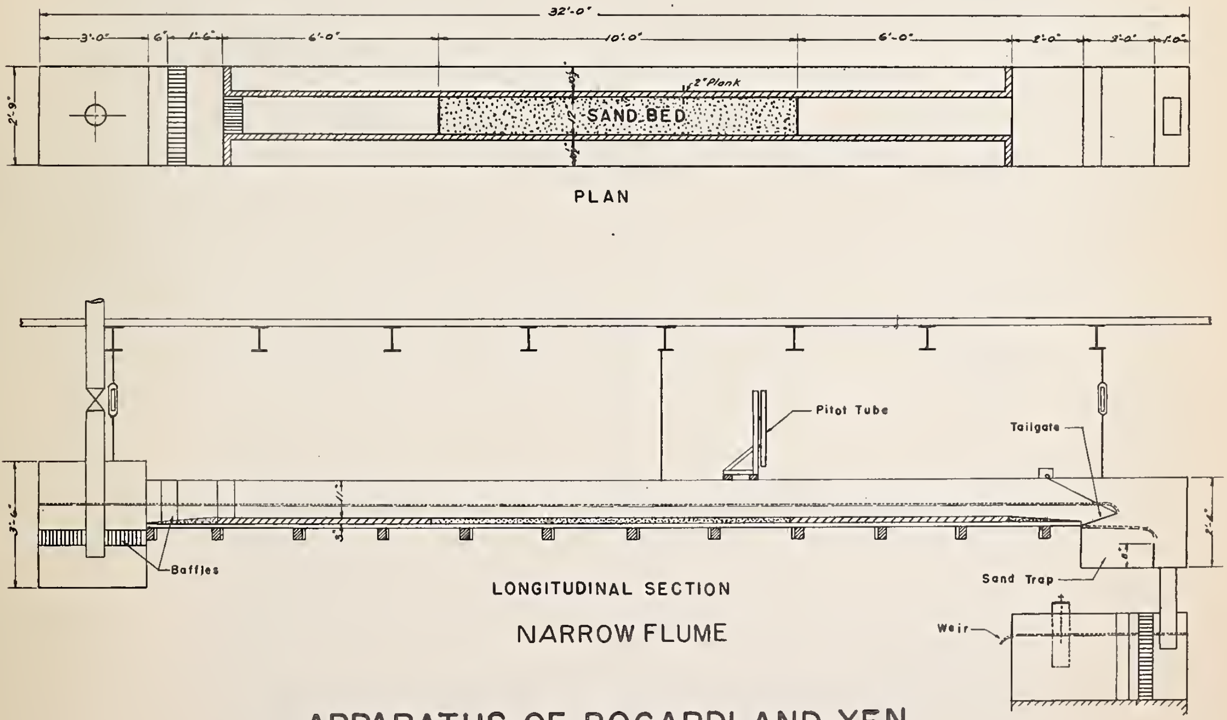
MATERIALS TESTED BY LIU

Figure 19



LONGITUDINAL SECTION

WIDE FLUME



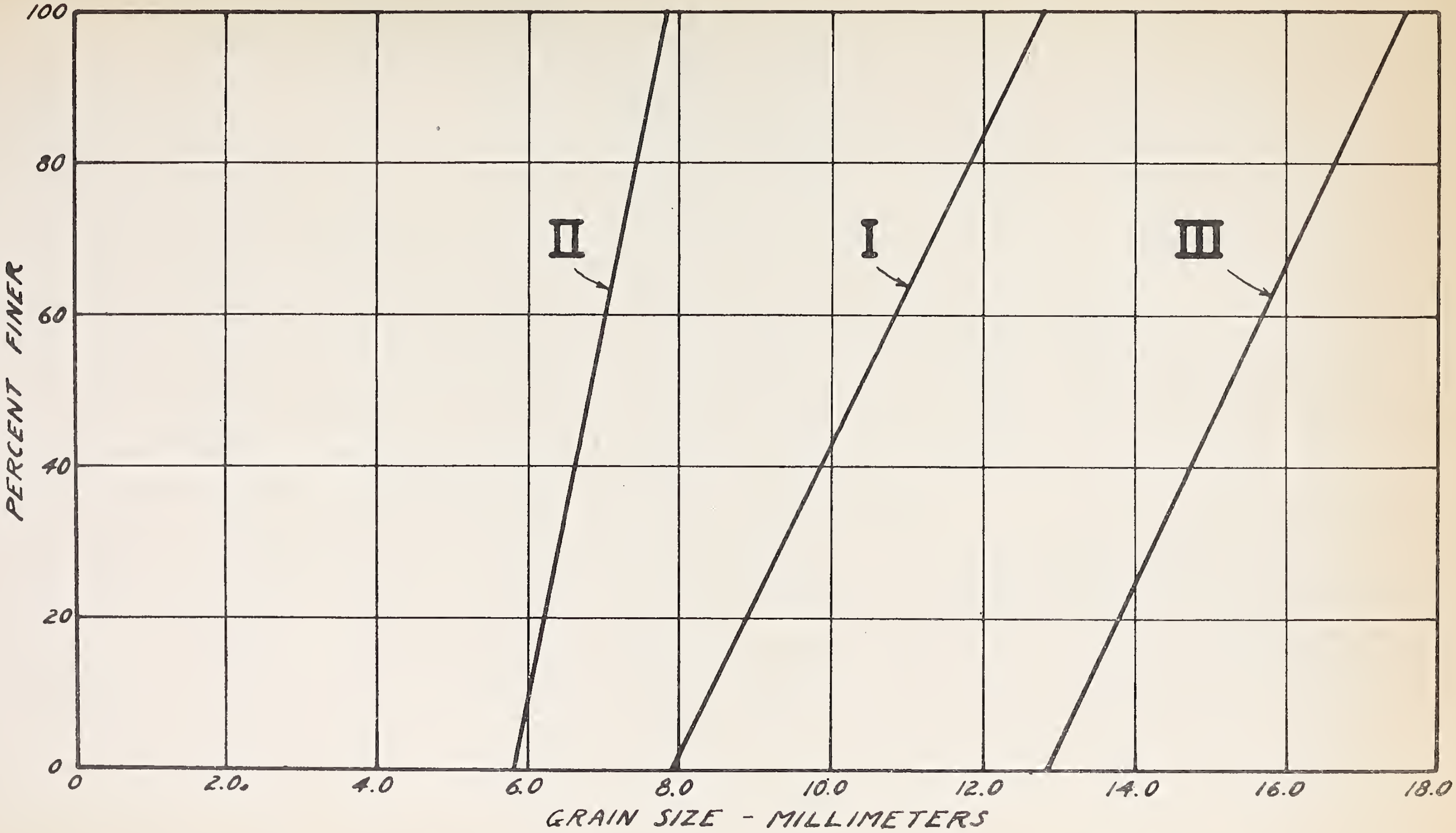
LONGITUDINAL SECTION

NARROW FLUME

APPARATUS OF BOGARDI AND YEN

Scale ½" = 1 Foot

Figure 20



MATERIALS TESTED BY BOGARDI AND YEN

Material Tested

A natural mixture of well-rounded material was obtained from Muscatine, Iowa, and screened into 3 grades, designated by the numerals I to III (items 104–106, table 1). The physical properties of these 3 unigranular materials are shown in table 15, and their mechanical analysis curves are shown in figure 20.

Table 15.—Summary of physical properties of materials tested by Bogardi and Yen

Material	Specific gravity	Size limits	Mean diameter	Uniformity modulus
		Millimeters	Millimeters	
I................	2.63	7.88–12.80	10.56	0.86
II................	2.61	5.82–7.88	7.12	.75
III................	2.64	12.80–17.58	15.49	.86

Experimental Procedure

With the slope adjusted to a desired value, the material to be tested was thoroughly mixed, placed in the recess in the false flow, and the surface made level with the flume bed. The discharge was started and increased slowly until bed movement started. The depth of the flow was regulated by the tail gate to maintain uniform flow conditions at all times. After data on depths, slope, rates of discharge, and velocity distribution had been recorded for conditions that appeared to be competent, the rate of flow was increased, the tail gate was raised to maintain essentially uniform flow, and the rate of bed-load transportation, in addition to the other factors, was measured.

To equalize the velocity distribution and roughness conditions, the false wooden floor upstream from the sand bed and the two side borders along the sand bed in the wide flume were covered with three-quarter-inch-mesh screen.

Data Appearing in Summary

With the exception of those runs in which no sand movement was recorded, all data appearing in tables 6 to 10, inclusive, of the original paper were used in preparing the summary presented in table 37.

In reducing the original data to that appearing in table 37, the same procedure as outlined in the sample calculation (pp. 5 to 7) was followed. In computing the hydraulic radius of the bed (column 10) Manning's n of the side walls was assumed to have the value of 0.011.

EXPERIMENTS BY M. P. O'BRIEN

This investigation (27), authorized by a War Department Special Board of Engineers in connection with beach-erosion investigations at the mouth of the Columbia River, was conducted at the University of California under the direction of M. P. O'Brien. The report describes a laboratory study of the rate of transportation of material forming the bed of the Columbia River.

Experimental Equipment and Measurements

The experimental flume was 43 feet long, 3 feet wide, and 18 inches deep, with slope adjustable by means of screw jacks. The transported material was caught in a sand trap 12 feet long, consisting of reversed vanes extending across the channel. A weighing pan located below the vanes permitted continuous weighing of the transported material.

The flow in the circulating water system was measured by means of a standard orifice and compared with a rectangular, sharp-crested suppressed weir. Water-surface elevations were measured by means of point gages located along the center line of the flume. Bed elevations and water depths were observed on cloth tapes fastened to the channel side walls. The profile of the bottom along the center line was measured after each run by means of a surveyor's level. Suspended-load samples were taken by means of a suction tube with a funnel-shaped opening. Water velocities were measured by floats and miniature current meters.

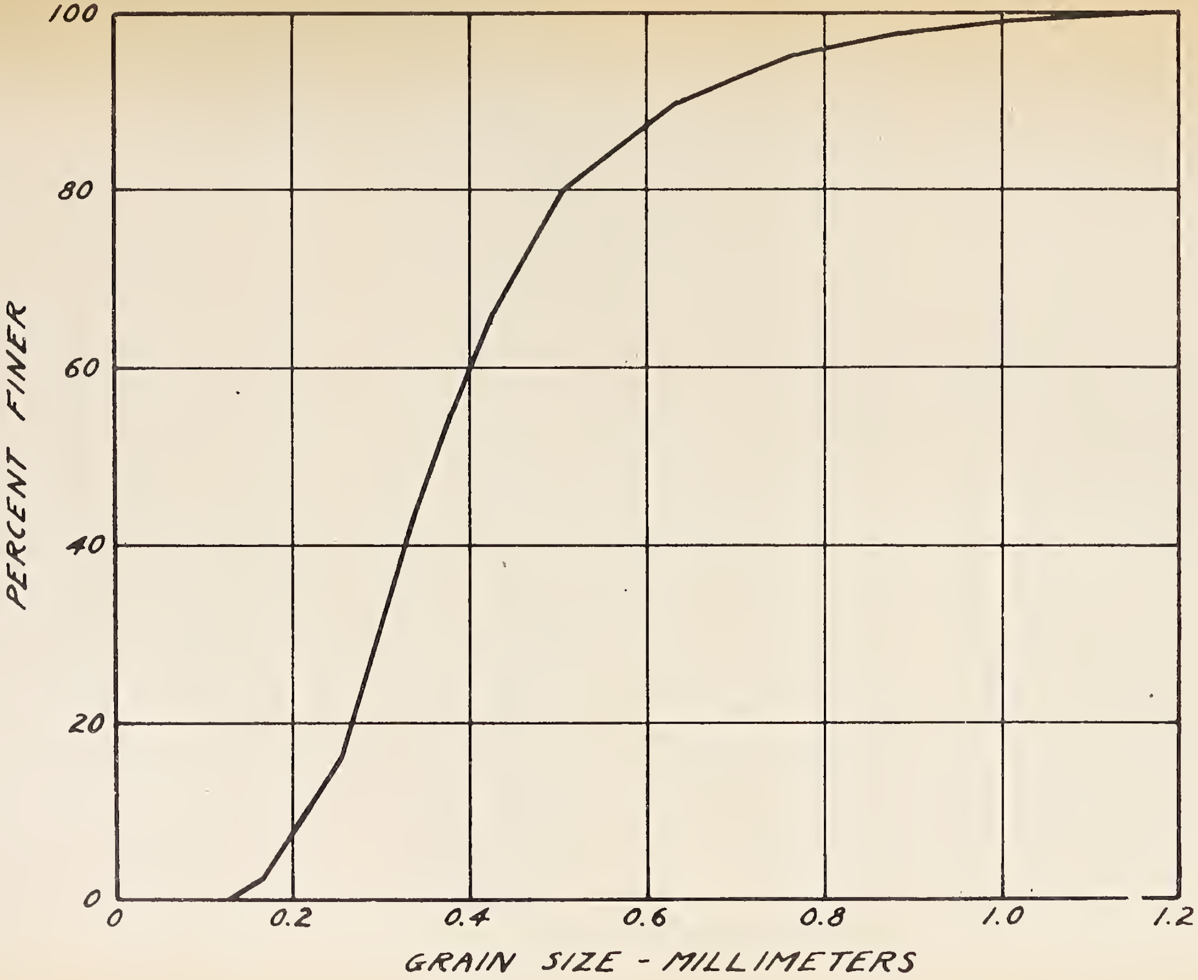
Material Tested

The sand tested was dredged from the Columbia River at lower Wanna Bar in 34 feet of water (item 107, table 1). The physical properties of this material was summarized in table 16, and its mechanical analysis curve is shown in figure 21.

Table 16.—Summary of physical properties of Columbia River sand

Material	Specific gravity	Size limits	Diameter		Phi standard deviation	Uniformity modulus
			Mean	Phi arithmetic mean		
		Millimeters	Millimeters			
Columbia River sand	2.57	0.127-1.168	0.366	+1.41	0.56	0.486

Figure 21



MATERIAL TESTED BY O'BRIEN

Experimental Procedure

At the beginning of a series of runs the bed was smooth. The discharge was increased by steps until the bed material just started to move. Further increases were made up to the maximum practicable velocity, and then the discharge was decreased by steps until sand movement ceased. The length of each run varied with the rate of sand movement. At high rates of transportation the sand trap filled so quickly that the material could not be weighed during the run and it was necessary to bring the flow and depth to the desired value very quickly, make the necessary observations, and then shut down abruptly. At low rates of movement, changes in the bottom occurred gradually and measurements did not need to be made simultaneously, but the length of run had to be as much as seven hours to attain the desired accuracy in weighing.

Three series of runs were included for approximate depths of 0.3, 0.5, and 1.0 foot.

The slope of the energy gradient, as recorded in the original report, was calculated from observed values of bed slope, water-surface slope, depth, and discharge.

The bottom slope was maintained at a constant value of 0.001 for all runs except run No. 30. For this run the bottom slope was 0.002.

Data Appearing in Summary

Experimental data appearing in tables I and II of the original report are summarized in table 38. Data are tabulated for only those runs in which the critical conditions were exceeded and the rate of sand movement recorded. Computations were made according to the sample calculation on pages 5 to 7.

EXPERIMENTS BY C. A. WRIGHT

At the request of the United States Bureau of Reclamation, tests (37) were made by the National Bureau of Standards hydraulic laboratory to obtain an experimental comparison of the scour produced in a bed of fine sand in a sloping flume by muddy water and by clear water, in an attempt to simulate the conditions existing in the Colorado River at Boulder Dam before and after construction.

Experimental Equipment and Measurements

The tests were made in a wooden flume 20 inches wide, 18 inches deep, and 40 feet long, with adjustable slope (fig. 22). The test sand bed was placed in the flume opposite a glass panel section 8 feet long. Water levels were controlled by means of a tail gate and were measured by means of a point gage traveling on the top of the flume. For the muddy-water experiments, kaolin was added to the supply basin and was thoroughly stirred into the water being pumped through the flume.

Vertical velocity curves were measured occasionally with a simple glass Pitot tube.

Materials Tested

A quantity of typical Colorado River sand (item III, table I) from Yuma, Ariz., was sent to the laboratory for the tests. As this sand appeared too fine to be used in developing the experimental procedure, a local commercial fine sand referred to as "asphalt sand" (item 108, table 1), also was obtained. The asphalt sand later was divided into coarse and fine portions (items 109-110, table 1) by means of a United States Standard No. 70 sieve (0.21 mm.). To simulate the suspended load, a kaolin from Georgia was used.

The physical properties of the various materials are summarized in table 17. Figure 23 shows the mechanical analysis curves for the Colorado River sand and the asphalt sand before screening.

Table 17.--Summary of physical properties of materials tested in scour experiments of C. A. Wright

Material	Size limits	Mean diameter	Uniformity modulus
	Millimeters	Millimeters	
Asphalt sand, clear water	0.043-1.651	0.336	0.333
Asphalt sand passing No. 70 sieve, clear water	0.000-0.210	.204	---
Asphalt sand retained on No. 70 sieve, clear water....................	.210-1.651	.384	---
Asphalt sand retained on No. 70 sieve, undispersed with kaolin......	.210-1.651	.342	---
Asphalt sand retained with No. 70 sieve, dispersed with kaolin.........	.210-1.651	.398	---
Colorado sand, clear water...........	0.000-0.417	.107	.50
Colorado sand, with undispersed kaolin	0.000-0.417	.109	.50

Experimental Procedure

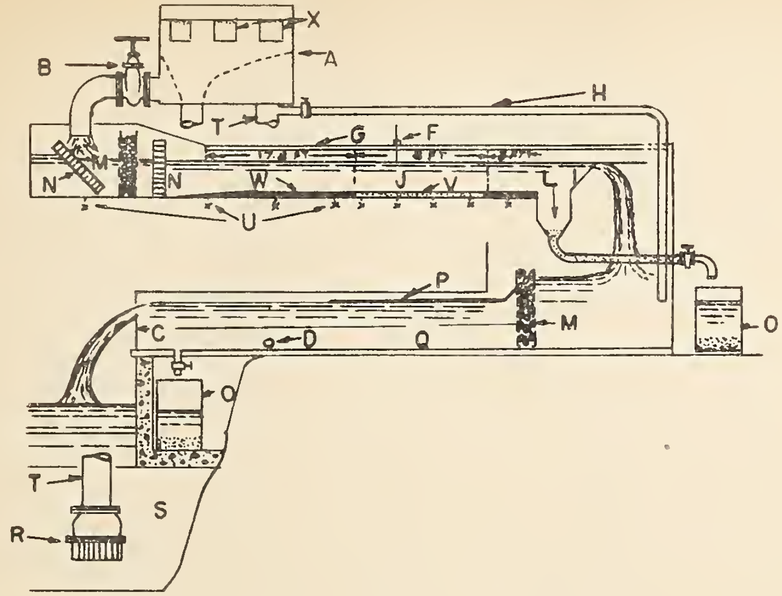
Wet sand was placed in the bed recess and the surface made smooth with a trowel. The tail gate was set, and the supply valve adjusted until the slope of the water surface was approximately parallel to that of the bed. The scouring and riffling of the sand bed were studied through the glass wall panel. At the end of an hour the experiment was stopped, the flume drained, and the characteristics of the bed noted. Samples of the bed material and trapped material were taken for analysis.

For the muddy-water experiment, the sand bed in the flume was settled in muddy water, and the clay in the supply basin was stirred thoroughly before each experiment. Four samples of the suspended load were taken during the experiment.

Data Appearing in Summary

During these experiments no bed material was added at the upper end of the flume to replace the material scoured from the bed and transported to the

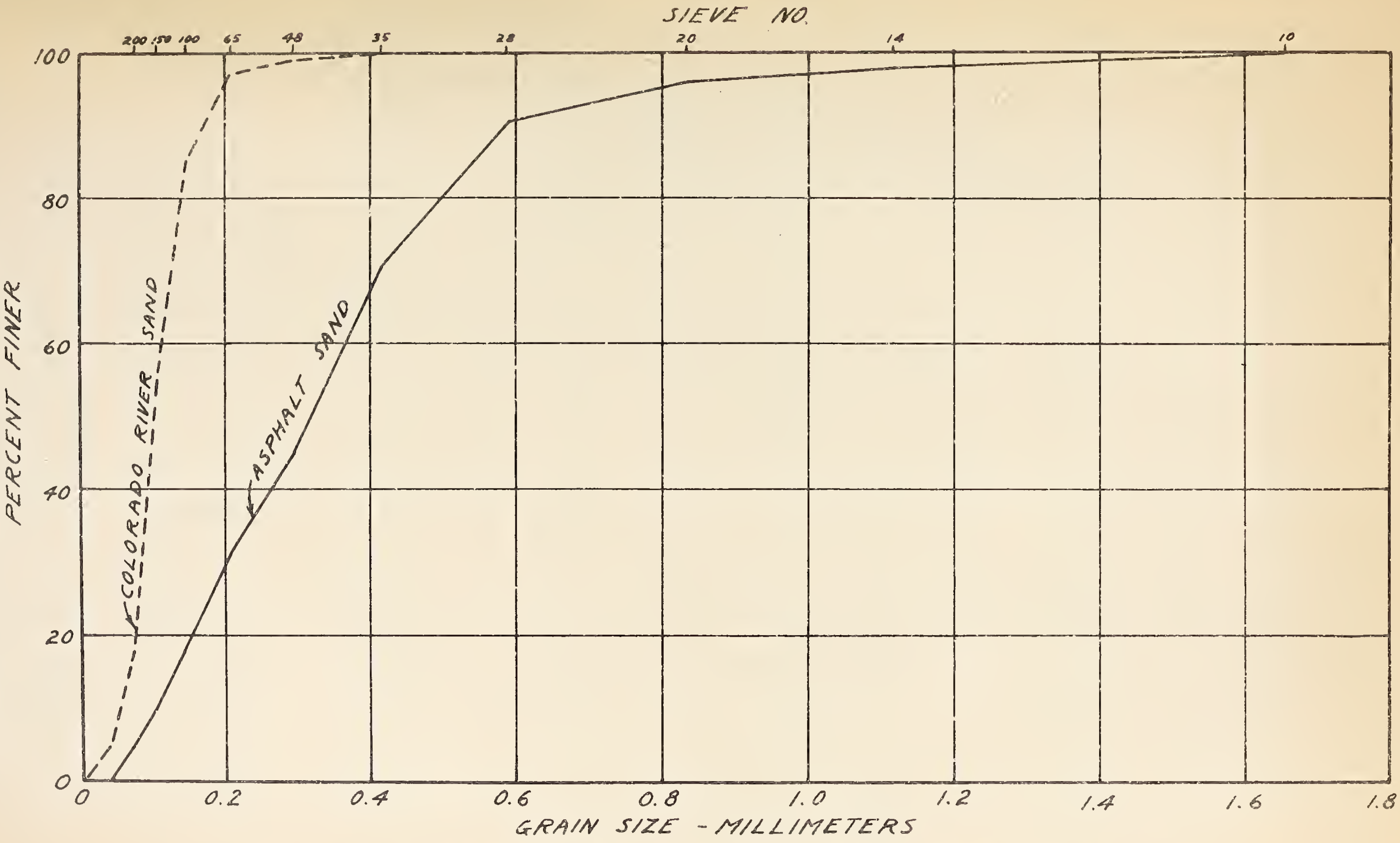
Figure 22



A	Constant level tank.
B	Supply valve
C	Weir.
D	Weir gage.
F	Point gage.
G	Brass rails.
H	By-pass pipe.
I	Tail gate.
J	Glass panel section.
L	Coarse sand trap.
M	Stone baffle.
N	Radiator baffle.
O	Sediment settling can.
P	Raft.
Q	Settling basin and weir forebay.
R	Foot valve - pump.
S	Supply basin.
T	Supply pipe - pump to tank.
U	Gage connections and drains.
V	Sand bed.
W	Approach floor.
X	Overflow troughs leading to overflow pipe.

APPARATUS OF SCOUR STUDIES OF C.A.WRIGHT.

Figure 23



MATERIALS TESTED BY WRIGHT

sand trap. Because of the relatively short length of the sand bed, it is believe that the velocity distribution as measured, more nearly represented conditions for flow over the concrete bed of the flume upstream from the sand bed, rather than flow over a bed of granular material. In view of these various limitations, the basic data from these tests were not considered applicable to the general problem of bed-load transportation and bed roughness, and hence are not summariz in this compilation of flume data.

LINTON BANK PROTECTION STUDIES

This series of experiments (48) was made at the Linton hydraulic laboratory, Portland, Ore., to obtain laboratory data more applicable than those available on the movement of the larger sizes of stones in flowing water and the velocitie required to move various sizes.

Experimental Equipment and Measurements

The facilities provided consisted of a fixed bed flume 6 feet wide, 5 feet deep, and about 130 feet long, with an available water supply of 70 cubic feet per second. A movable bed 45 feet long of various sized stone, with suitable transitions up and downstream, was placed in this flume (fig. 24), and the velocities that caused "general movement" of the bed were observed. For some of the experiments a transverse slope from the center of the flume of 1 on 1-1/2 or 1 on 2 was given to the bed. For stone larger than 3 inches, the bed was shortened to 10 feet in length, and the high velocities required were obtained by installing an adjustable weir with a sloping downstream face just upstream from the bed (fig. 25).

The discharge was measured by the two 6-foot rectangular weirs, and velocity distributions were measured by means of a Hoff current meter. The water surfaces in the flume were usually determined by piezometer connections and a hook gage (figs. 24 and 25).

Materials Tested

The materials tested in these experiments consisted of both well-rounded gravel and angular crushed stone. The materials were segregated into uniangular sizes by means of a series of sieves. The physical properties of the various sizes tested are summarized in table 1, (items 112-137).

Experimental Procedure

Preliminary to the tests on stone movements, a series of stone-dropping experiments was made to determine the downstream drift of the stones before striking bottom, and of the distance moved after striking the bottom. These stone-dropping experiments were similar to the experiments described in United States Waterways Experiment Station Technical Memorandum No. 69-1 (see p. 24).

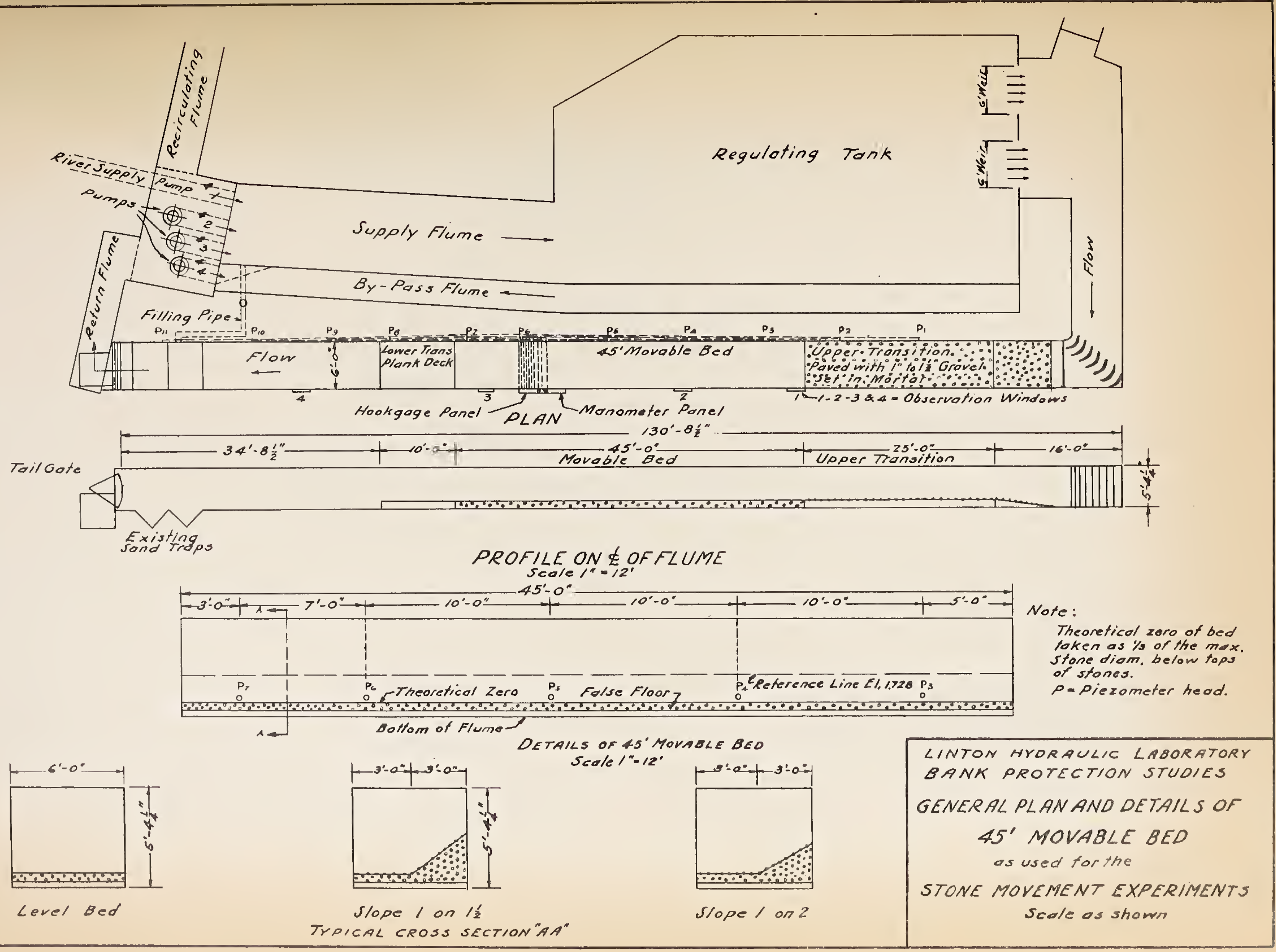
The stone-movement experiments were divided into two main groups. The first group was carried out using a 45-foot movable bed (fig. 24). The material composing the movable bed was carefully placed in the flume to prevent segregation of size. Prior to each run, the material was screened by means of wooden templates running on removable straight edges fastened to the side of the

Table 18.—Summary of stone movement experiments at Linton Hydraulic Laboratory

Experiment No.	Material	Condition of bed			Quantity	Mean depth	Mean velocity	Bottom velocity		Duration	Amount moved
		Length	Longitudinal slope	Transverse slope				Maximum and minimum	Average		
	Inches	Feet			C.f.s.	Feet	F.p.s.	F.p.s.	F.p.s.	Hours	Pounds
SM 1-1	1 - 1½ G[1]	45	--	--	67.2	1.89	5.9	3.9-5.2	4.4	2	Not recorded
2-1	1 - 1½ G	45	--	1 on 1½	67.4	2.53	5.5	2.8-4.3	3.8	3	Not recorded
3-1	3/4 - 1 G	45	--	--	69.2	2.04	5.6	3.8-4.7	4.2	2	173
4-1	3/4 - 1 G	45	--	1 on 1½	34.6	1.72	4.7	2.7-4.1	3.5	2	Not recorded
4-2	3/4 - 1 G	45	--	1 on 1½	69.2	2.82	5.0	3.1-3.8	3.4	2.5	Not recorded
5-1	1/2 - 3/4G	45	--	--	68.8	2.13	3.4	3.7-4.7	4.1	2.5	584
5-2	1/2 - 3/4G	45	--	--	34.5	1.30	4.4	3.2-4.2	3.7	2	41
6-1	1/2 - 3/4G	45	--	1 on 2	23.2	1.35	3.9	3.1-3.8	3.3	1.5	24
6-2	1/2 - 3/4G	45	--	1 on 2	43.7	2.03	4.4	2.4-3.9	3.3	2.17	36
6-3	1/2 - 3/4G	45	--	1 on 2	67.8	3.02	4.3	2.1-3.6	3.0	2.5	12
7-1	3/8 - 1/2G	45	--	--	23.0	1.04	3.7	2.9-3.6	3.3	2	19
7-2	3/8 - 1/2G	45	--	--	49.2	2.02	4.1	3.0-3.4	3.3	2	14
7-3	3/8 - 1/2G	45	--	--	67.8	2.69	4.2	2.9-3.6	3.3	2.25	19
8-1	1/4 - 3/8G	45	--	--	20.9	1.03	3.4	2.8-3.4	3.1	2	28
8-2	1/4 - 3/8G	45	--	--	43.2	2.00	3.6	2.5-3.6	2.8	2.33	5
8-3	1/4 - 3/8G	45	--	--	67.5	2.81	4.0	2.6-3.3	3.1	2	83
9-1	1 - 1½ G	45	0.0054	--	68.2	1.82	6.2	3.9-5.3	4.6	2	257
10-1	2 - 3 G	45	.010	--	68.7	1.73	6.6	4.0-5.5	4.4	2	143
11-1	2 - 3 G	10	--	--	68.3	1.75	6.5	--	--	2	215
12-1	2 - 3 C.R.[2]	10	--	--	69.0	1.57	7.3	5.9-9.0	6.8	2	380
13-1	2 - 3 C.R.	10	.02	--	68.6	1.66	7.3	5.3-6.9	6.1	2	73
14-1	3 - 4 G.	10	.02	--	69.0	1.68	6.8	3.5-6.3	5.3	2	75
15-1	4 - 5 G	10	.02	--	69.0	1.50	7.7	5.7-7.0	6.5	2	142
16-1	5 - 6 G	10	.02	--	66.5	1.33	8.6	3.8-8.9	7.1	2	146
17-1	3 - 4 C.R.	10	.02	--	69.0	1.63	7.0	4.7-6.2	5.6	2	42
18-1	1 - 1½ G.	10	--	--	69.0	2.30	5.0	4.0-4.6	4.3	2	15

[1] G = Gravel. [2] C.R. = Crushed rock.

Figure 24

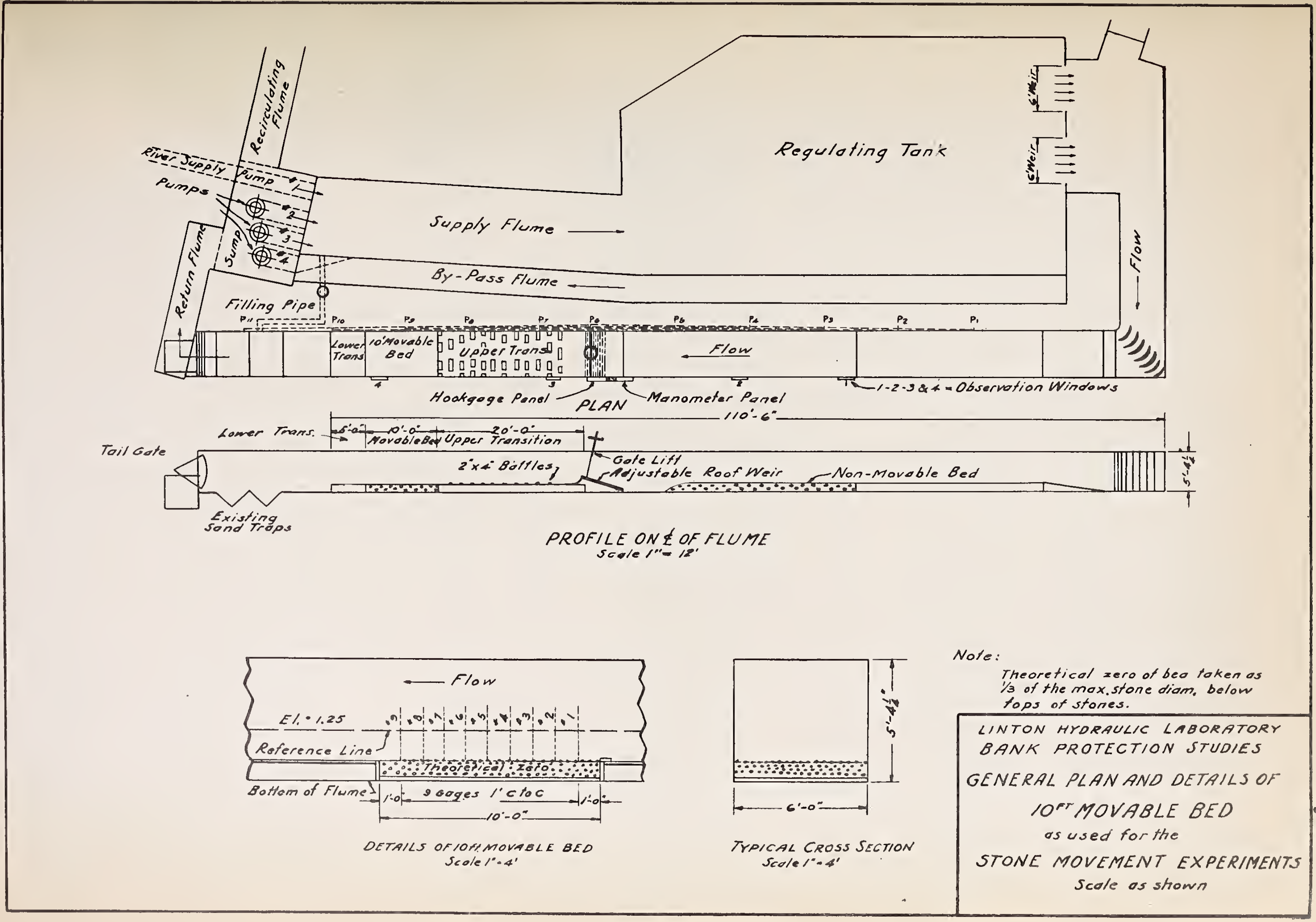


Note:
Theoretical zero of bed taken as ⅓ of the max. stone diam. below tops of stones.
P = Piezometer head.

LINTON HYDRAULIC LABORATORY
BANK PROTECTION STUDIES

GENERAL PLAN AND DETAILS OF
45' MOVABLE BED
as used for the
STONE MOVEMENT EXPERIMENTS
Scale as shown

Figure 25



Note:
Theoretical zero of bea taken as 1/3 of the max. stone diam. below tops of stones.

LINTON HYDRAULIC LABORATORY
BANK PROTECTION STUDIES
GENERAL PLAN AND DETAILS OF
10 FT MOVABLE BED
as used for the
STONE MOVEMENT EXPERIMENTS
Scale as shown

flume. The thickness of the movable bed varied from 8 to 14 inches.

For each experiment, one run was made by first filling the flume slowly, and gradually increasing the depth until intermittent movement occurred. The procedure for additional runs consisted of filling the flume to the desired depth (1, 2, or 3 feet) and gradually increasing the discharge while maintaining that depth until movement occurred.

After establishment of the critical conditions causing movement, each run was continued for a definite period of time, usually two hours. During this time velocity distributions were measured at two sections.

The second group of stone-movement experiments was carried out using a 10-foot movable bed placed below an adjustable roof weir temporarily constructed within the flume (fig. 25). This arrangement permitted larger sizes of gravel and crushed rock to be moved than was possible with the longer bed. The genera procedure of carrying out these experiments, however, was similar to that alread described for the 45-foot movable bed.

In neither case was material added at the upper end of the movable bed to replace that transported out of the lower end.

Data Appearing in Summary

As these experiments were primarily a study of scour, similar to the studie of Liu and Carter (42) (p.29) and Wright (37), and, therefore, are not comparable with other experiments on bed-load transportation and bed roughness, non of the experimental data have been summarized, according to the standard method described on pages 5 to 7. A brief summary, however, of the more general resul of the experiments is given in table 18.

EXPERIMENTS BY F. SCHAFFERNAK

This series of experiments (32) was conducted at the Versuchsanstalt fur Wasserbau, Vienna, and was intended to give information on the relation between the capacity of a stream and its bottom velocity.

Experimental Equipment and Measurements

The experiments were conducted in a glass-walled channel 100 centimeters wide (fig. 26). Water was discharged through a bottom sluice, 5 centimeters high, across the width of the channel and flowed in a thin sheet over a planed wood floor 100 centimeters long between the sluice and a pit containing the material under investigation. The sand pit was 50 centimeters long and was provided with 5 transverse plates, supporting sand, which could be raised to maintain the sand-surface level with the approach floor. Sand moved was caught in a settling basin at the lower end of the channel.

Material Tested

Materials used in the tests (items 138-169, table 1) were obtained from the Danube River at Vienna, and they had a mean specific gravity of approximately 2.

The material was first separated on sieves ranging from 3 to 100 millimeters clear opening and then, as required, was recombined according to the 4 types of gradation curves described as follows and shown graphically in figure 26:

Type I. Material of uniform size. The sizes tested were 3, 5, 10, 12, 14, 16, 20, 25, 30, 50, and 70 millimeters in diameter.

Type II. Mixture having little fine material and relatively large proporti of course particles. Seven mixtures made from particles ranging in size from 0 to 3, 0 to 5, 0 to 10, 0 to 16, 0 to 20, 0 to 30, and 0 to 50 millimeters were used.

Type III. Uniformly graded mixture. Seven mixtures with the same range in particle sizes as type II were used.

Type IV. Mixture having little coarse material and a relatively large proportion of fine materials. Seven mixtures with the same range in particle sizes as type II were used.

Both round and flat grains were used in the experiments.

Experimental Procedure

Schaffernak was attempting to simulate conditions existing near the bottom of a channel, and the average velocity of his 5 centimeter layer was to correspond to the bottom velocity in an open channel. The experimental procedure consisted of increasing the head on the supply tank until the velocity along the bottom just started material to move. The velocity was then increased in steps and the rate of removal of material weighed. The surface of the sand was always kept flush with the level of the approach section.

Data Appearing in Summary

Schaffernak's method of generating his velocity undoubtedly must cause a varying velocity distribution throughout the length of the channel. Furthermore it is doubtful if the velocity distribution in his 5-centimeter depth of flow would correspond to the velocity distribution in a 5-centimeter layer near the bottom of a deep stream. His data on the larger sizes of materials (greater tha 16 mm.) that were large in comparison with the 5-centimeter depth, are of doubtf value.

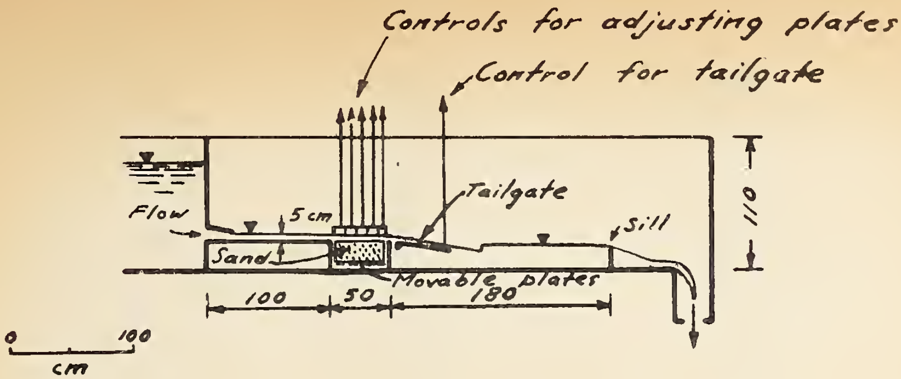
In view of these considerations, which indicate that Schaffernak's data give information merely on scouring velocities and yield no information that is comparable with other experiments on bed-load transportation and bed roughness, the basic data are not summarized according to the standard method of this repor

For a brief discussion in English of Schaffernak's conclusions, the reader is referred to the publication of Mavis, Ho, and Tu (23).

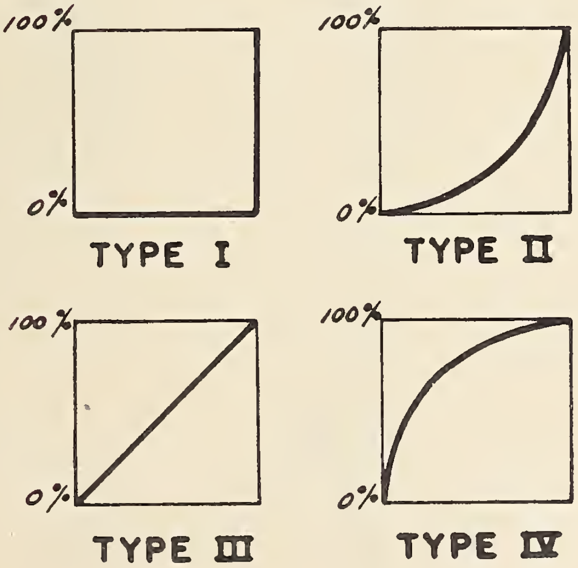
EXPERIMENTS BY E. MEYER-PETER

These experiments (10, 25) were made in the hydraulic laboratory of the Federal Institute of Technology, Zurich, Switzerland.

Figure 26



APPARATUS OF F. SCHAFFERNAK



TYPE I

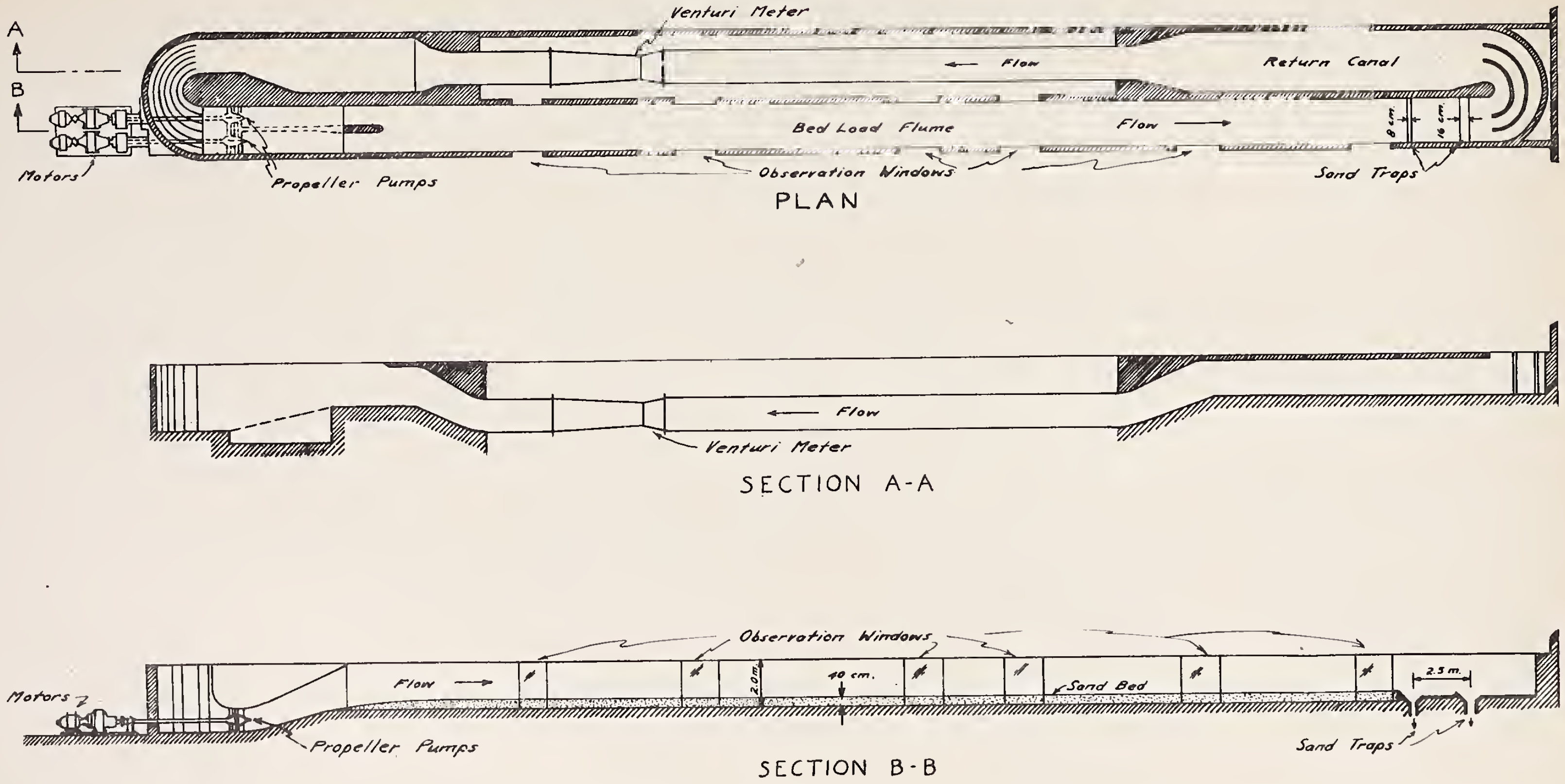
TYPE II

TYPE III

TYPE IV

TYPES OF MIXTURES TESTED

Figure 27



APPARATUS OF MEYER-PETER

Experimental Equipment and Measurements

The tests were conducted in a flume 2.0 by 2.0 meters in section, 50 meters long, with an effective length of 28 meters, and with a piezometer arrangement for measurement of the water surface and bed (fig. 27). Water was circulated in the system by 2 propeller-type pumps. Discharges up to 5 cubic meters per second (177 c.f.s.) could be obtained and were measured by a 5-foot diameter automatic recording Venturi meter. Determination of the position of the water surfac was made by 5 piezometer tubes which tapped into the flume under the bed. Adjustment of the depth of flow was made by regulating the volume of water in the system. An automatic variable-speed, sand-feeding device of 4-cubic-meter capacity was located at the entrance end of the flume. A settling hopper on the lower end of the flume had a capacity of 3.5 cubic meters.

Material Tested

Various uniform grain sizes of gravel, coal, and barite were tested (items 170-173, table 1). Two sizes of gravel were used. One size with a mean grain siz of 28.6 millimeters was that material passing a 34-millimeter sieve and retained on a 24-millimeter sieve. The other and smaller size of gravel was $4\sqrt{2}$ times smaller than the larger size. It had a mean diameter of 5.21 millimeters and wa obtained by sieving between 6 and 4.25-millimeter sieves. A single size of coal (sp. gr. 1.25) and of barite (sp. gr. 4.22) was prepared by sieving the material through 6 and 4.25-millimeter sieves, the mean grain diameter thus being 5.21 millimeters, the same as the smaller size of gravel.

The physical properties of the various materials tested are shown in table 19.

Table 19.--Summary of physical properties of materials tested at the Swiss Federal Institute of Technology

Material	Specific gravity	Size limits	Mean diameter	Uniformity modulus
		Millimeters	Millimeters	
Gravel..........	2.65	24 -34	28.6	0.84
do	2.65	4.25-6.00	5.21	.84
Coal	1.25	4.25-6.00	5.21	.84
Barite..........	4.22	4.25-6.00	5.21	.84

Experimental Procedure

With a particular material in the flume, water was circulated at a chosen discharge and depth until no systematic bed changes appeared to occur. An experiment was then started and usually consisted of eight or more runs in which measurement of slope, discharge, rate of transportation, and condition of bed wa made. The duration of normal run corresponded to the time required to feed 2.8 cubic meters of material into the upper end of the flume, but in no case did a run exceed 6 hours. Experiments with water depths above 0.5 meter were repeat for 2 different entrance conditions, that is, degrees of turbulence. Runs were started and stopped by suddenly starting and stopping the pumps.

The only deviation from similitude (Froude) between the large-scale experiments (material 28.6 mm. in diameter) and the small-scale experiments (material 5.21 mm. in diameter) was in the roughness of the flume side walls. By elimination of the side-wall effect, however, similarity between those forces acting only on the bed was obtained.

Data Appearing in Summary

Because of unsettled European conditions, permission to include the basic data obtained in these experiments has not been obtained and consequently is not included in this summary. These data, however, have been used by H. A. Einstein in preparing his recent publication on bed-load transportation (10).

EXPERIMENTS BY HANS KRAMER

This study (20) was made at the Prussian Experiment Institute for Hydraulic Engineering and Shipbuilding, Berlin, for the purpose of determing a suitable bed material for the modeling of rivers in which bed load is in motion at the lowest stages.

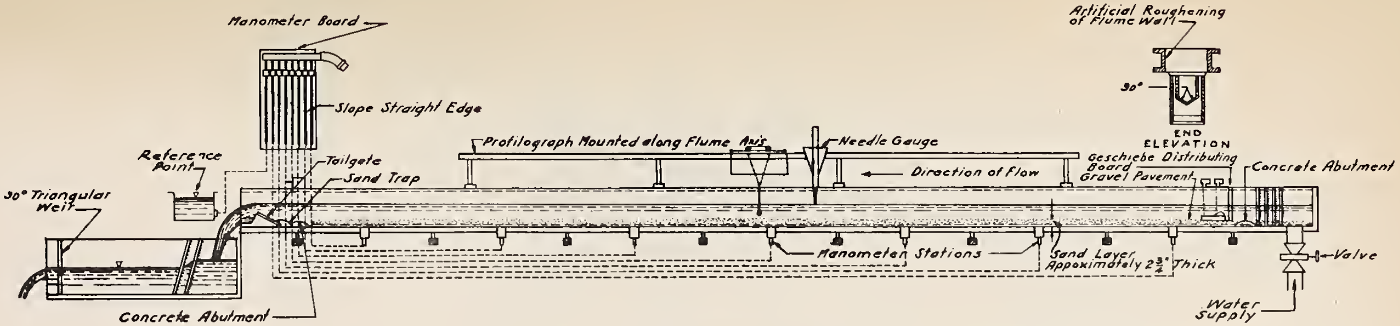
Experimental Equipment and Measurements

An open flume, 14 meters long and of rectangular cross section, 80.7 meters wide by 30 meters deep, was used for these experiments (fig. 28). The vertical interior walls of the flume were artifically roughened with grains of sand, 2 to 3 millimeters in diameter, sprinkled on a coating of wet oil paint to which the grains adhered after the paint dried. The position of the water surface was determined from piezometer tubes located at frequent intervals along the flume. Depth of flow was measured by a point gage. Discharge was measured by means of a V-notch weir.

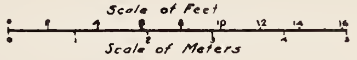
Sand was introduced in a moist condition from an adjustable distributing board at the upper end of the flume. This distributing board also served as a float for stilling the inflowing water. Sand that was trapped at the lower end of the flume was measured volumetrically in a tin vessel with a capacity of approximately 1 liter.

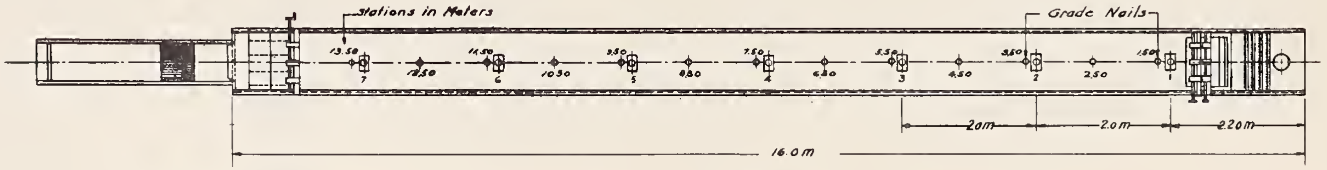
Materials Tested

Mixtures were prepared by sieving a well-rounded quartz pit sand into three classes (items 174-176, table 1). The physical properties of the various sands are summarized in table 20, and their mechanical analysis curves are shown in figure 29.



LONGITUDINAL SECTION

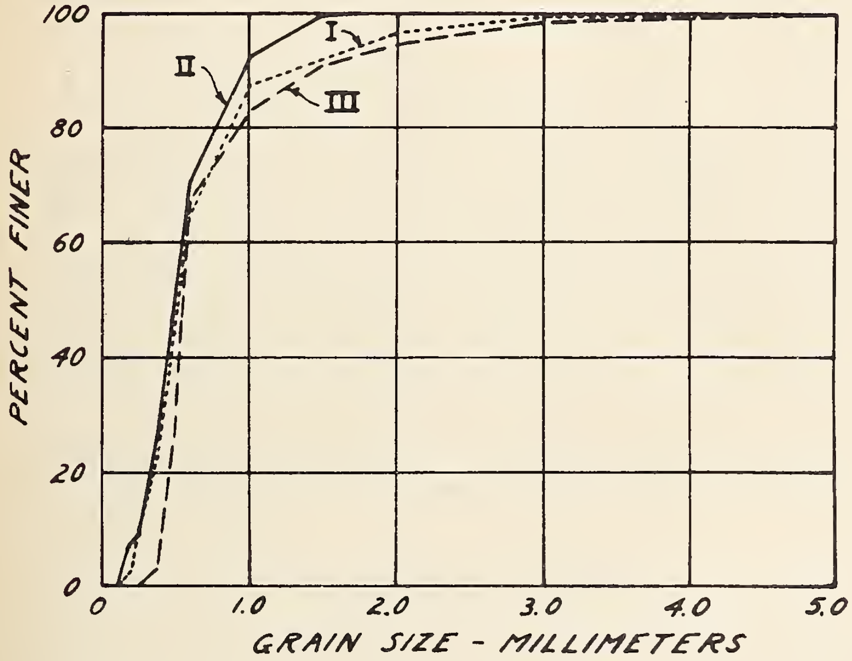




PLAN

APPARATUS OF KRAMER

Figure 28



MATERIALS TESTED BY KRAMER

Table 20.—Summary of physical properties of materials tested by Hans Kramer

Material No.	Specific gravity	Size limits	Mean diameter	Uniformity modulus
		Millimeters	Millimeters	
I................	2.70	0.208-5.00	0.705	0.358
II...............	2.70	.208-1.77	.558	.461
III..............	2.70	.385-5.00	.800	.414

Experimental Procedure

Each experiment was started with very shallow depth of flow, which was increased gradually to permit determination of the point at which bed-load movement began. With further increasing depths, observations of the movement of bed load and the formation of sand riffles were made. The depth was then observed at which the upper limit of usefulness of the mixture, as determined by the appearance of disturbing sand riffles, was reached. The depth of flow was regulated by varying the discharge, at the same time regulating the tail gate to maintain the required constant slope.

Each mixture of the sand was tested with 4 bottom slopes, 1:400, 1:600, 1:8 and 1:1,000. The water-surface slope was maintained constantly equal to the bottom slope.

Data Appearing in Summary

Although the author mentions in his original paper that the rate of bed-loa transportation was measured, a record of these data do not appear in his table of experimental data, hence, a summary, compiled according to the standard method described on pages 5 to 7 has not been made.

EXPERIMENTS BY H. J. CASEY

This series of experiments (4) was made at the Prussian Experiment Institut for Hydraulic Engineering and Shipbuilding, Berlin.

Experimental Equipment and Measurements

The experimental flume was 14 meters long by 40 centimeters wide, and 50 centimeters deep with glass side walls. The discharge was measured by a V-notch weir. The position of the water surface was determined from piezometer tubes located at 1-meter intervals along the flume bottom. Depth of flow was measured by a point gage. Measurements of depth and slope were made in an 8-meter reach in the center of the flume. Surface velocities were determined by float measurement.

Sand was introduced by hand uniformly across the flume at the entrance, in quantities equal to that being settled in the sand trap. The rate of bed-load transportation was determined by volumetric measurement.

Materials Tested

Three types of mixtures, designated as A, B, and C, each of nearly the same mean grain diameter, but with widely different uniformity modulus, were used (items 177-193, table 1). In each type of mixture, 3 groups of grain sizes were used, namely group I (0 to 1.02mm.), group II (0 to 2mm.), and group III (0 to 3 mm.). The types of mixtures were:

Mixture A.—A mixture of many fine and coarse grains but few medium-sized ones.

Mixture B.—A mixture with a straight-line distribution curve.

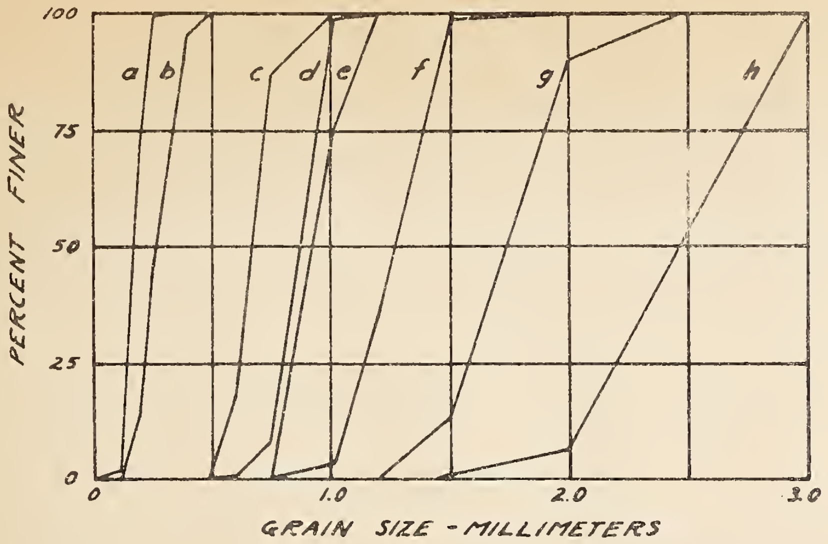
Mixture C.—A mixture of many medium grains and few fine or coarse ones.

Eight unigranular materials (items 177-184, table 1), which were used in preparing the mixtures A, B, and C, also were tested. The physical properties of the 3 mixtures and 8 unigranular materials are summarized in table 21, and their mechanical analysis curves are shown in figure 30.

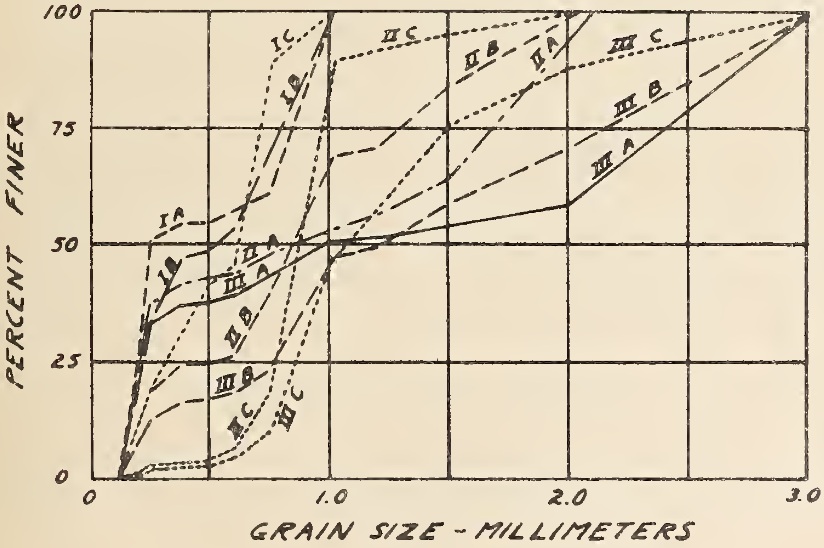
Table 21.—Summary of physical properties of materials tested by Hugh J. Casey

Material No.	Size limits	Mean diameter	Uniformity modulus
	Millimeters	Milli-meters	
a	0-0.25	0.175	0.716
b	0.12-0.49	.263	.645
c	.49-1.02	.68	.804
d	.60-1.02	.87	.830
e	.75-1.20	.938	.799
f	1.02-1.50	1.26	.812
g	1.20-2.50	1.747	.790
h	1.50-3.00	2.455	.789
IA	0. -1.02	.50	.235
IIA	0. -2	.92	.145
IIIA	0. -3	1.32	.147
IB	0. -1.02	.52	.296
IIB	0. -2	.90	.359
IIIB	0. -3	1.37	.303
IC	0. -1.02	.53	.465
IIC	0. -2	.90	.677
IIIC	0. -3	1.25	.492

Figure 30



UNI-GRANULAR MATERIALS



SYNTHETIC MIXTURES

MATERIALS TESTED BY CASEY

Experimental Procedure

Each experiment was started with a shallow depth of flow, which was increased gradually to permit determination of the point at which bed-load movement began. With further increasing depths, observations on the rate of bed-load movement were made. The measurements were carried out with rising stages, so that a definite bed formation was built up. Following this and without remolding the bed, measurements were made for the falling stage. The depth of flow was regulated by varying the discharge, at the same time regulating the tail gate to maintain the water-surface parallel to the slope.

Each of the 3 mixtures and the 8 unigranular sands was tested with at least 3 bottom slopes ranging from 1:200 to 1:1,200.

Data Appearing in Summary

With the exception of those runs in which no bed-load movement was recorded, all the data appearing in appendix B of the original publication were used in preparing the summary presented in table 39. It is to be noted that the only experimental data appearing in appendix B were for 1 unigranular sand (sand h at 3 slopes, 1:200, 1:400, and 1:800) and 1 sand mixture (mixture A-III at 3 slopes, 1:400, 1:800, and 1:1,200). Although the data for the other sands are available upon request from the Prussian Experiment Institute, unsettled European conditions have prevented procurement of this material.

In reducing the original data for sands h and A-III to that appearing in table 39 the same procedure as outlined in the sample calculation (pp. 5 to 7) was followed. In computing the hydraulic radius of the bed (column 10) Manning's n at the glass sidewalls was assumed to have the value 0.0080, and in reducing the rate of bed-load transportation from a volumetric value, as recorded in the original publication, to a weight value, the sand was assumed to weigh 1.75 grams per cubic centimeter.

EXPERIMENTS BY A. SHIELDS

This series of experiments (35) was made at the Prussian Experiment Institute for Hydraulic Engineering and Shipbuilding, Berlin.

Experimental Equipment and Measurements

The rectangular wooden flume of 80-centimeter width used by Kramer (see fig. 28) was used in the experiments on barite mixtures I, II, and III, and on brown coal mixtures I, II, III. For the experiments with barite the walls were made of lacquered wood, and for the experiments with brown coal, the walls were made approximately to the same roughness as the bed by gluing coal particles to the walls.

For the experiments on barite mixtures IV and V and the amber materials, the rectangular glass flume of 40-centimeter width used by Casey (see p. 43) was used.

Measurement of the position of the bed and water surface was made by means of point gages. In the experiments on barite, velocity distributions were measured by means of a Pitot tube.

Materials Tested

A summary of the physical properties of the various materials tested (items 194-206, table 1) is shown in table 22, and their mechanical analysis curves are shown in figure 31.

Table 22.—Summary of physical properties of bed materials tested by A. Shields

Material	Specific gravity	Size limits	Mean diameter	Uniformity modulus
		Millimeters	Millimeters	
Amber	1.06	0.38-3.0	1.56	0.58
Brown coal I	1.27	.75-2.0	1.77	.39
Do II	1.27	.75-5.0	1.88	.39
Do III	1.27	2. -5.	2.53	.55
Granite fragments I	2.69	2. -3.	2.44	.79
Do II	2.71	1.02-1.5	1.23	.83
Do III	2.70	.75-1.02	.85	.81
Barite I	4.2	3. -4.	3.44	.82
Do II	4.19	2. -3.	2.46	.78
Do III	4.2	1. -2	1.52	.67
Do IV	4.25	.49- .75	.69	.67
Do V	4.3	.25- .49	.36	.67
Do VI	4.2	2. -5.	2.70	.68

Experimental Procedure

Each material was investigated with an average of 4 different slopes. For each slope approximately 16 different water depths were obtained by gradually increasing the discharge and regulating the tail gate. Each run was contined until the bed appeared to be in a state of equilibrium before measurement of depth, slope, and rate of bed-load transportation was made. The various measurements were made similar to the methods of Kramer (p.43) and Casey (p.45).

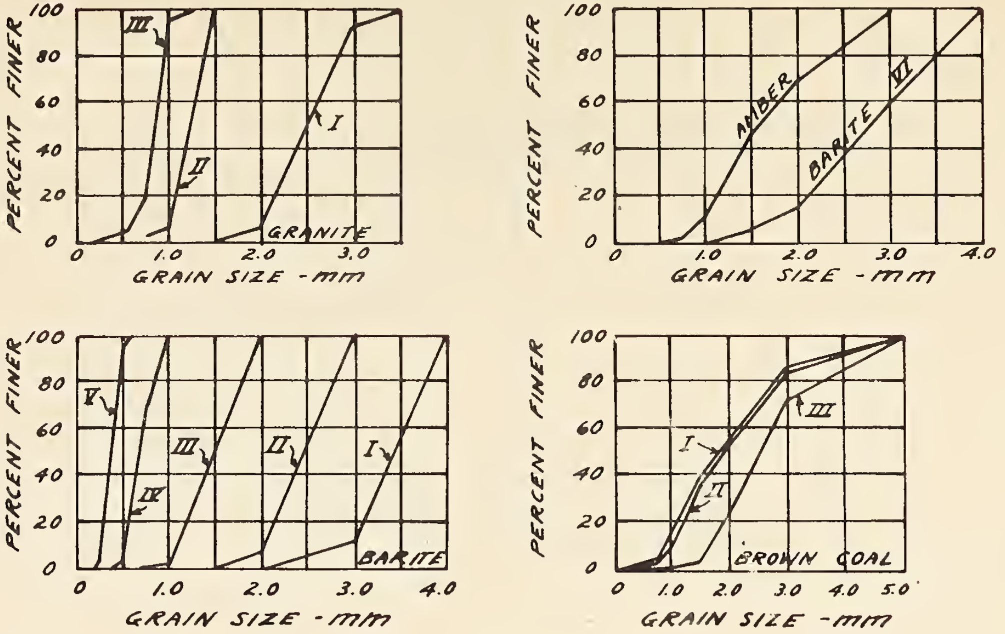
Data Appearing in Summary

Since none of the experimental data is tabulated in the original publicatio and since it has not been possible to obtain the data from the Prussian Experimen Institute because of unsettled European conditions, a summary of data, according to the standard system described in pages 5 to 7, of course, is not possible.

EXPERIMENTS BY PANG-YUNG HO

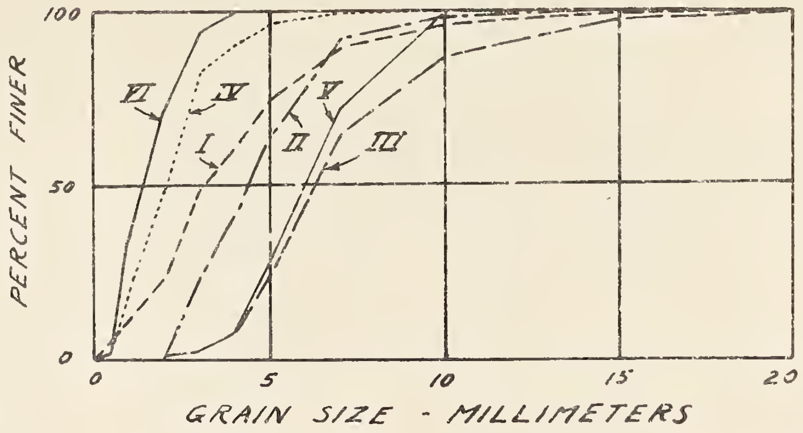
This investigation (15), which was conducted at the Prussian Experiment Institute for Hydraulic Engineering and Shipbuilding, Berlin, consisted of three parts. First, studies were made with flat materials to determine the nature of

Figure 31



MATERIALS TESTED BY SHIELDS

Figure 32



MATERIALS TESTED BY HO PANG-YUNG

their movement, the critical conditions for movement, and the rate of transportation. Secondly, tests were conducted on a rounded material to determine the effect of temperature on rate of transportation. Thirdly, fall velocity experiments were made on the flat materials studied in the first part.

Experimental Equipment and Measurements

The experimental flume was 16 meters long, by 40 centimeters wide, and 56 centimeters deep, with glass sidewalls. The discharge was measured by a V-notch weir. The position of the water surface was determined from piezometer tubes located at frequent intervals along the flume. Measurements of the depth of flo were made by point gages located at 5 points along the center line of the flume. Surface velocities were determined by float measurements.

Sand was introduced by hand uniformly across the flume, at the entrance, in quantities equal to that being discharged. The rate of bed-load transportation was determined by volumetric measurement.

Materials Tested

In these experiments five mixtures of flat particles and one mixture of rounded particles were used (items 207-212, table 1).

The flat particles were obtained from the Ruhr River, near Aachen, Germany, and the five mixtures (materials I-V) prepared by sieving. Mixture VI, used in the temperature experiments, was a rounded quartz sand. A summary of the physical properties of the six mixtures is shown in table 23, and the mechanical analysis curves are shown in figure 32.

Experimental Procedure

Each experiment was started with a shallow depth of flow, which was increased gradually to permit determination of the point at which bed-load movement began. With further increasing depths, observations on the rate of bed-load movement were made. The depth of flow was regulated by varying the discharg at the same time regulating the tail gate to maintain the water surface parallel to the bed slope.

The slope of the bed was adjusted by the tilting of the flume. The slope of the water surface could be determined both from readings on the piezometer tubes and on the point gages. The following slopes were used:

Mixture I.—— 1:100, 1:800, 1:600, and 1:300
Mixture II.— 1:800, 1:600, 1:300
Mixture III.– 1:600, 1:300, 1:200
Mixture IV.— 1:1,000, 1:800, 1:600
Mixture V.—— 1:300, 1:200
Mixture VI.— 1:1,000

Data Appearing in Summary

With the exception of those runs in which no bed-load movement was recorded, all the data appearing in tables 1 and 2 of the original publication were used in preparing the summary. In reducing the original data for mixtures I to V to that appearing in table 40 the same procedure as outlined in the sample calculations on pages 5 to 7 was followed. In computing the hydraulic radius of the bed (col. 10) Manning's n of the glass sidewalls was assumed to have the value 0.0080.

In those experiments on mixture VI the effects of viscosity due to the wide range in temperature were probably appreciable, in which case the Manning formula is not adequate for calculating the hydraulic radius of the bed. In such a case a friction formula which includes a factor for viscosity must be used for that part of the flow, where viscosity forces are appreciable; that is, for flow in contact with the sidewalls. A formula of this type is the law for flow in smooth pipes, the application of which is described by J. W. Johnson (18). This method was used in the calculation of the hydraulic radius of the bed (col. 10), and then this value was used in the calculation of friction velocity (col.11), Reynolds number (col. 12), Manning's n (col. 12), and the unit discharge (col. 14).

The rate of bed-load transportation for the experiments on both flat and round particles was determined volumetrically. In reducing these volumetric values, as recorded in the original publication, to weight values, the material was assumed to weigh 1.75 grams per cubic centimeter.

Table 23.—Summary of physical properties of materials tested by Pang-Yung Ho

Mixture No.	Specific gravity	Size limits	Mean diameter	Uniformity modulus
		Millimeters	Millimeters	
I.............	2.58	0. -20	3.83	0.313
II............	2.58	2. -15	4.64	.502
III...........	2.58	2. -20	6.99	.530
IV............	2.58	.5-10	2.18	.372
V.............	2.58	2. -10	6.17	.624
VI............	—	0. -4	1.55	.371

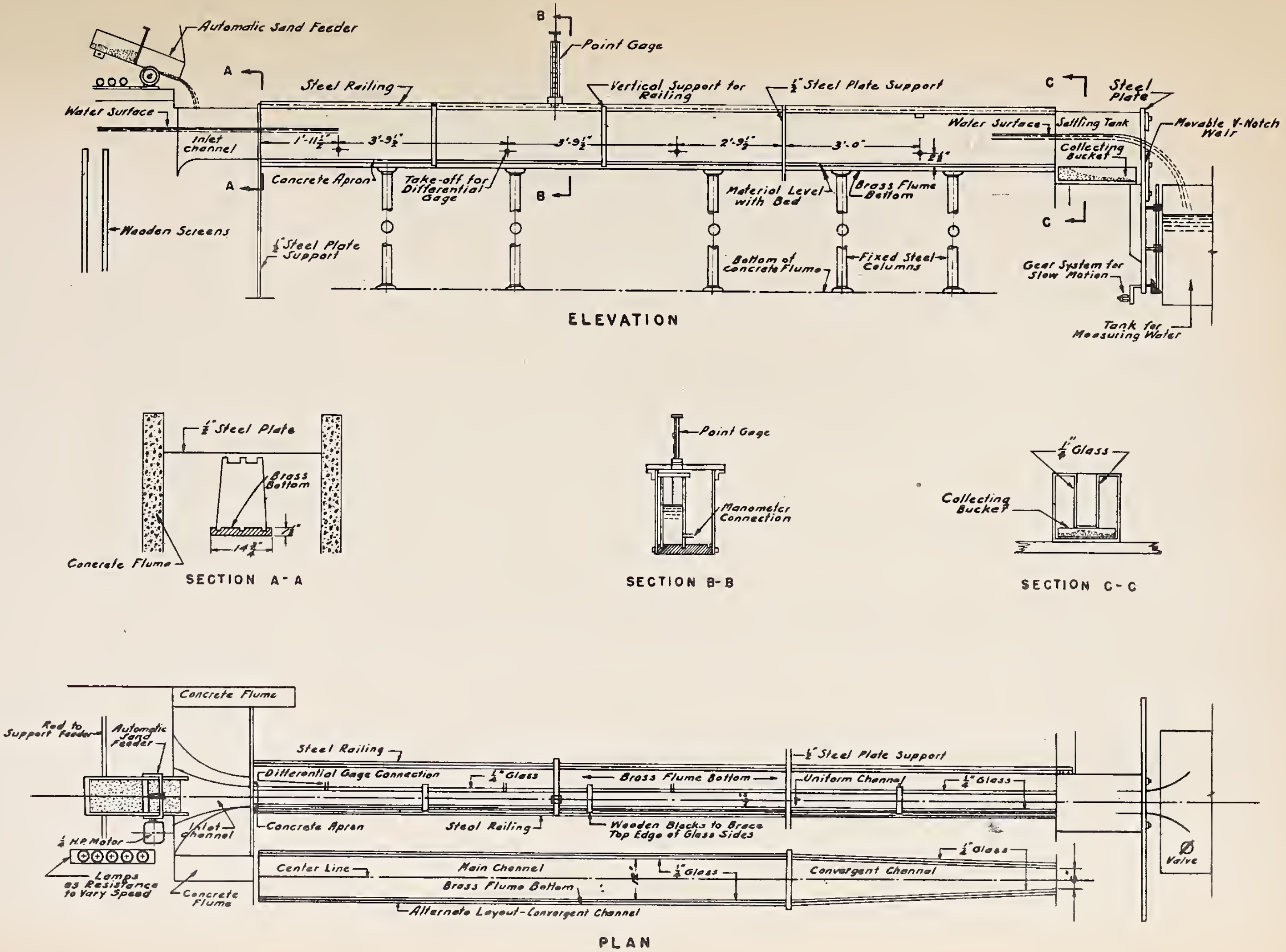
EXPERIMENTS BY Y. L. CHANG

This series of experiments (5) was made at Victoria University, Manchester, England.

Experimental Equipment and Measurements

In the laboratory flume used in these experiments 3 different arrangements were possible (fig. 33): (1) A uniform channel 18 feet long and 12 inches wide; (2) a uniform channel 18 feet long and 6 inches wide; and (3) a uniform channel

Figure 33



GENERAL ARRANGEMENT OF APPARATUS OF CHANG

12 feet long and 12 inches wide, followed by a 6-foot length of channel converging to a width of 6 inches at its downstream end. A point gage, Pitot tube, and template for smoothing the bed were arranged to slide on rails on top of the flume.

The water discharge could be measured either by means of a diaphragm in the feed pipe or volumetrically in a tank at the downstream end of the flume.

Materials Tested

In all, 12 commercially sieved samples were tested in the flume, each sampl consisting of grains of more or less uniform size (items 213-224, table 1). The average grain diameter varied from 8.090 millimeters for the coarsest sample to 0.134 millimeter for the finest. The principal mechanical properties are listed in table 24.

Table 24.—Mechanical properties of materials tested by Y. L. Chang.

Sample designation	Specific gravity	Mean grain diameter
		Millimeters
6205	2.547	8.090
6204	2.558	6.540
6203	2.567	5.290
6202	2.590	3.770
6201	2.633	2.540
6200	2.634	1.760
6199	2.640	.886
6198	2.643	.396
6197	2.645	.226
Pumice	2.053	.289
Pumice W	2.016	.317
Emery	3.890	.210
Sand X	2.520	.134

Experimental Procedure

In these experiments the bed was always molded horizontally instead of inclined to the same slope as the water surface. It would be possible to correct to the condition of uniform flow by subtracting the loss of potential head, due to the acceleration of flow, from the observed drop of surface level; however, it was the author's feeling that, over a riffled bed, any such correction is meaningless, for the surface waves are of the same order of amplitude as the riffles.

In beginning a test run, the bed material was first placed in the flume in a wet condition and made perfectly level and smooth. Flow was started with the depth controlled by regulation of the discharge and the tail gate.

When sand movement began, the water discharge was kept constant for a while for movement to become stabilized, before measurement of slope, depth, and rate of bed-load transportation was made. The flow was next increased a little to generate stronger movement of the bed. This procedure was continued until resul over a large range in depth were obtained.

Data Appearing in Summary

Because the author's publication did not include a tabulation of experiment measurements, and because the original thesis could not be obtained due to unsettled European conditions, a summary of data according to the standard system described on pages 5 to 7 is not possible.

EXPERIMENTS BY E. INDRI

This series of experiments (16) was made at the Royal Engineering Institute, Padova, Italy.

Experimental Equipment and Measurements

The experimental flume was 8 meters long, and 0.375 meter wide, with side walls artifically roughened by gluing sand of the same size as that forming the bed to the walls. The discharge was measured by a V-notch weir. The depth of the water was determined by means of 3 micrometer point gages, capable of measuring to one-tenth millimeter, located two meters apart. A bank of piezomet tubes was also used to determine the water-surface slope. The slope of the flum was adjusted by means of screw jacks.

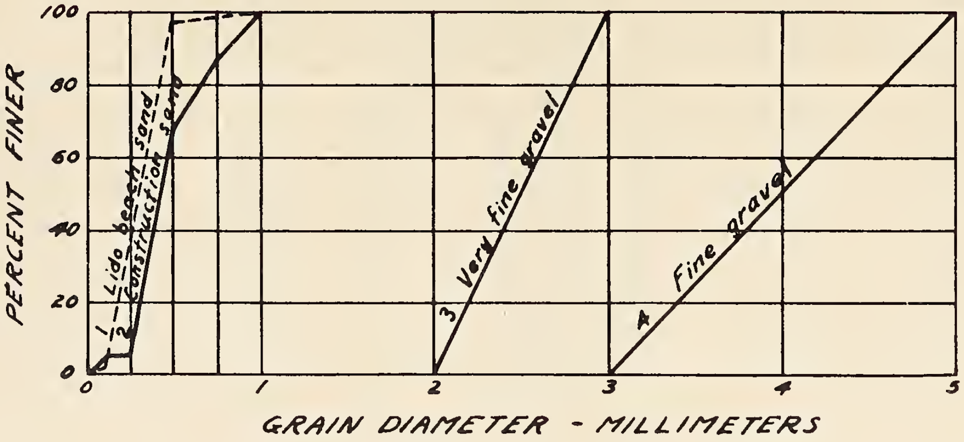
Materials Tested

Two sand mixtures and two gravel mixtures were tested in the experiments (items 225-228, table 1). A summary of the physical properties of the four mixtures is shown in table 25, and the mechanical analysis curves are shown in figure 34.

Table 25.—Summary of physical properties of materials tested by E. Indri

Mixture No.	Specific gravity	Size limits	Mean diameter	Uniformity modulus
		Millimeters	Millimeters	
1...............	2.63	0-1	0.324	0.690
2...............	2.70	0-1	.474	.481
3...............	2.70	2-3	2.5	.818
4...............	2.70	3-5	4.	.777

Figure 34



MATERIALS TESTED BY INDRI

Mixture 1 was a Lido beach sand obtained near Venice. Mixture 2 was sand used in ordinary construction work. Mixtures 3 and 4 were obtained near Brenta and were classed as very fine gravel and fine gravel, respectively.

Experimental Procedure

Material was placed in the experimental flume to a depth of 3.5 centimeters. The bed was made smooth and the flume then adjusted to the desired slope by means of screw jacks. Water was first let into the flume so as not to disturb the bed, and then the discharge was slowly increased until movement started. The water surface was kept parallel to the bed surface by manipulation of the tail gate. When general movement was reached, measurements of the depth and slope were made to determine the value of the critical tractive force. General movement in these experiments was defined as the condition existing when all particles, from the smallest to the largest, were in motion.

The various mixtures were tested at the following slopes:

Mixture 1.—Bed horizontal, 1:500, 1:333
Mixture 2.—Bed horizontal, 1:500, 1:333, 1:200
Mixture 3.—1:200, 1:125, 1:111
Mixture 4.—1:200, 1:100, 1:80

Data Appearing in Summary

Since these experiments were made to determine the value of the critical tractive force of the various materials, and give no information on the rate of bed-load transportation, the various experimental data have not been summarized.

EXPERIMENTS BY E. INDRI

This series of experiments on the movement of large-sized bed material was made at the Royal Engineering Institute, Padova, Italy.

Experimental Equipment and Measurements

One steel and two wooden tilting flumes were used in these experiments. No mention, however, is made of their dimensions. A maximum discharge of 150 liters per second (5.3 c.f.s.) was used and was measured by means of a weir. The depth of the water and the position of the water surface were determined by means of micrometer point gages. The gages were capable of measuring to one-tenth of a millimeter; however, because of the roughness of the surface, measurements closer than one-half of a millimeter were not possible.

Materials Tested

Four unigranular materials and two synthetic mixtures were tested in the experiments (items 229-234, table 1). A summary of the physical properties of the 6 materials is shown in table 26, and the mechanical analysis curves are shown in figure 35.

Table 26.—Summary of physical properties of large-sized bed material tested by E. Indri

Material No.	Specific gravity	Size limits	Mean diameter	Uniformity modulus
		Millimeters	Millimeters	
1.............	2.65	15-25	20	0.600
2.............	2.65	25-60	45	.715
3.............	2.65	60-100	80	.770
4.............	2.65	100-150	125	.815
5.............	2.65	10-150	58.8	.225
6.............	2.65	20-150	58.8	.280

Experimental Procedure

The material to be tested was placed in the experimental flume and the surface made smooth. Water was first let into the flume without disturbing the bed, and then the discharge was slowly increased until movement started. When general movement prevailed, measurements of the depth and water-surface slope were made to determine the critical tractive force. As in Indri's previous experiments, general movement was defined as the condition existing whe all particles from the smallest to the largest were in motion.

Data Appearing in Summary

As in the previous experiments by Indri, these tests were made to determin the value of the critical tractive force of the various materials. Since no information was given on the rate of bed-load transportation, the various experimental data have not been summarized.

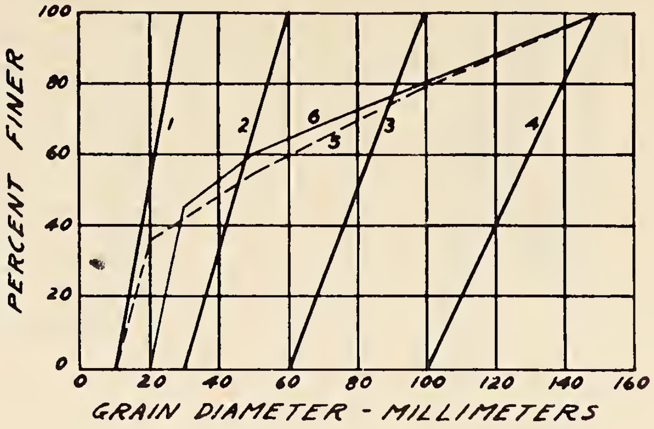
EXPERIMENTS BY H. NAKAYAMA

This series of experiments (26) was made at Tokyo Imperial University, Tokyo, Japan, to ascertain for a portion of a self-formed channel the change of forms of cross section, the variation of slope of the water surface, the volume of sand carried along the bed, and the relation between the surface slope of the water course at a given point and the volume of sand transported.

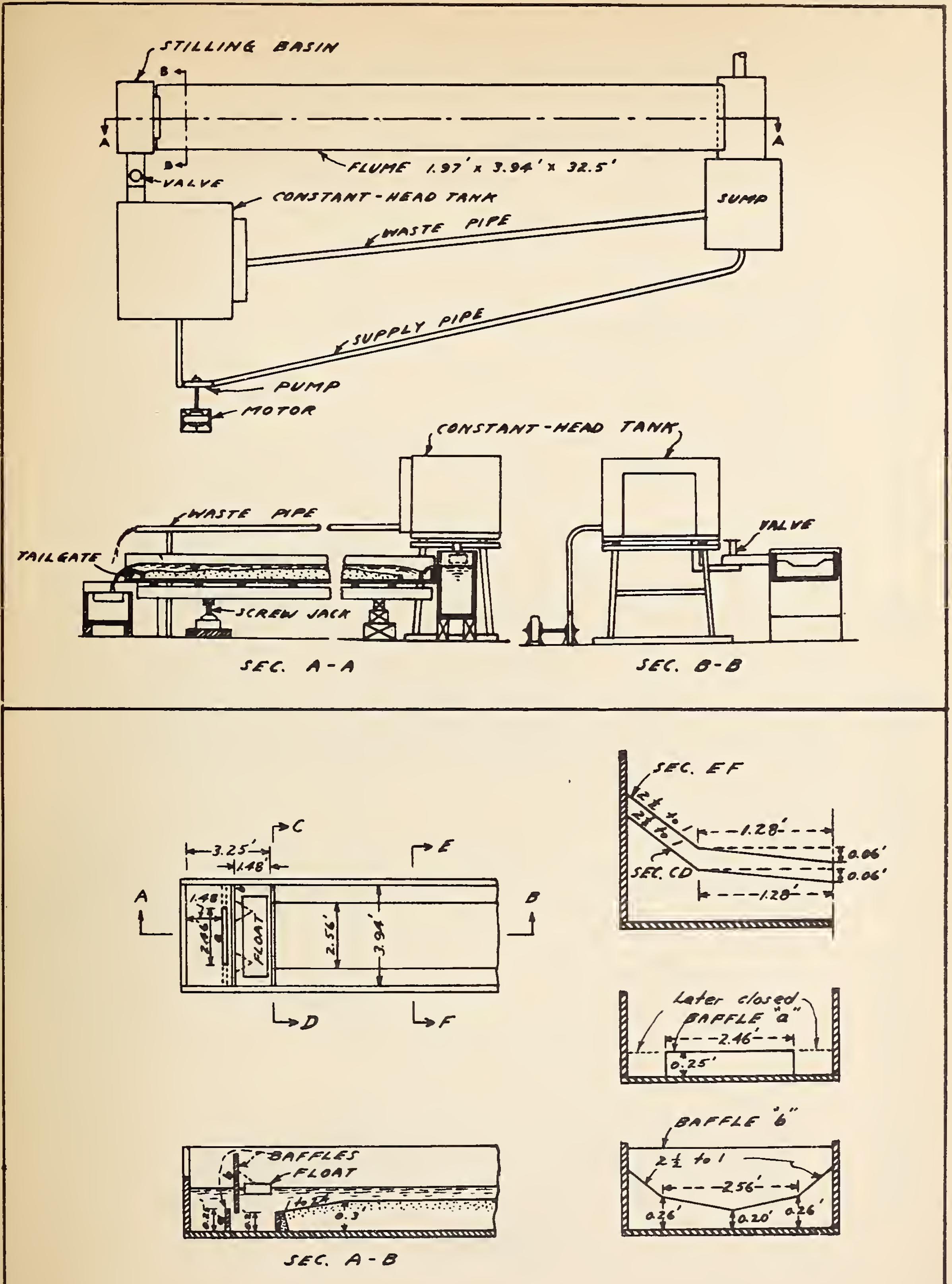
Experimental Equipment and Measurements

The apparatus shown in figure 36 consisted of a 32.5-foot tilting flume, 3.94 feet wide and 1.97 feet deep. Various forms of inlets were tried, but the greater part of the experiments was conducted with the inlet shown in figure 36. The sand in the channel was molded to a given form by means of a templet fastened to a carriage which could be moved along rails on the sides of the

Figure 35

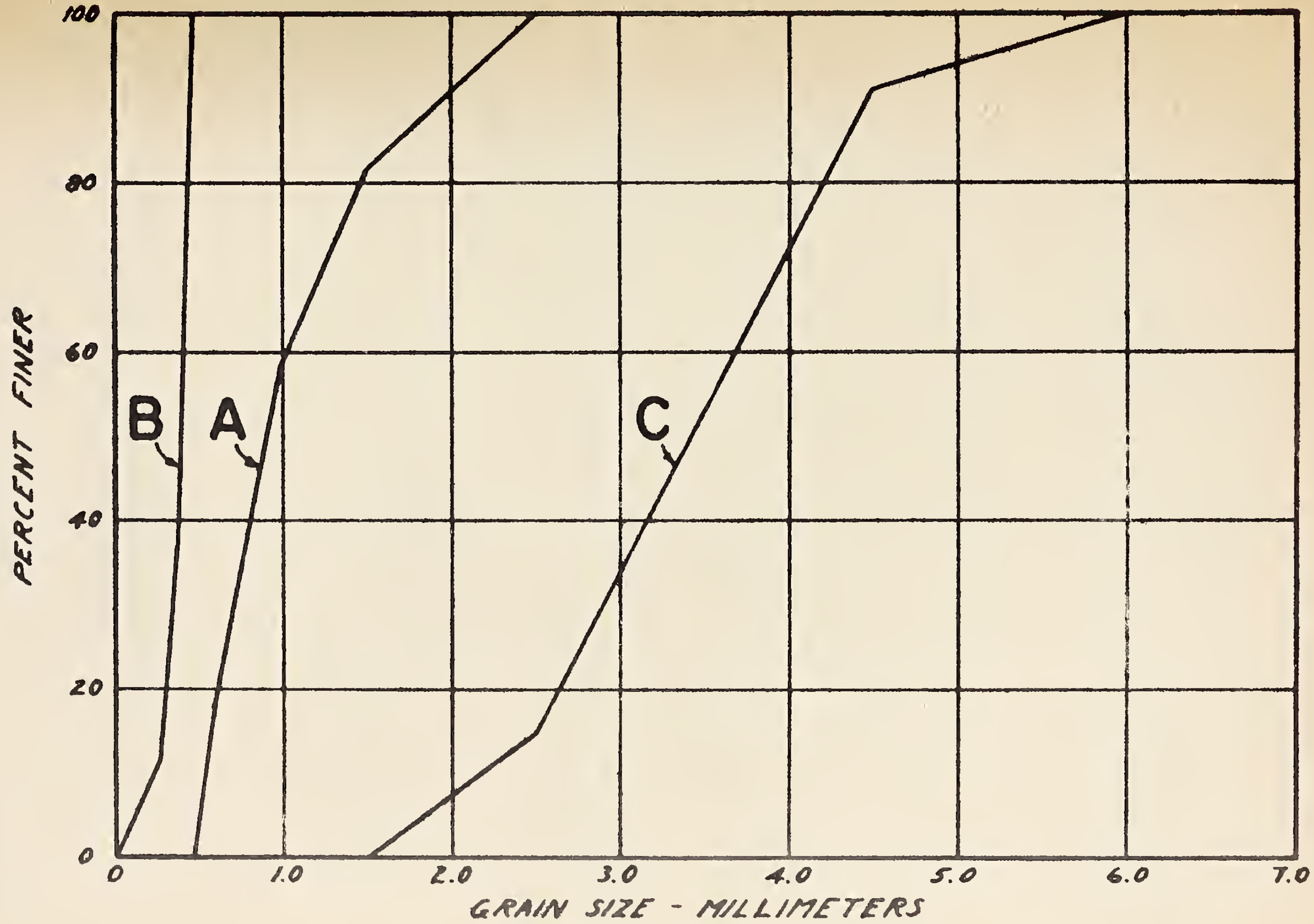


COARSE MATERIALS TESTED BY INDRI



APPARATUS OF NAKAYAMA

Figure 37



MATERIALS TESTED BY NAKAYAMA

flume. The water discharge was determined by a calibrated valve located in the supply line leading from the constant-head tank to the flume inlet. Positions of the water level and the bed were measured by means of point gages located at intervals along the flume. A check on the position of the water surface was afforded by means of several differential oil gages also located at intervals along the flume.

Materials Tested

Four synthetic sand mixtures were used in these experiments (items 235-238, table 1). The mechanical analysis curves of the first three of these materials (sands A, B, and C) are shown in figure 37. Sand D is a mixture of equal portio of each of sands A, B, and C; however, no mention is made as to whether this combination was made on a weight or a volume basis.

Experimental Procedure

The slope of the flume was adjusted to a particular slope, and then the sand bed was molded to a desired cross section. As to discharge of water, two cases were tried, one with a constant discharge and another with a varying discharge. In cases of constant discharge, the regulating valve was opened to give the required discharge and at the same time the tail gate was raised so that the flow of water would not disturb the sand bed. Next, the tail gate was lowered gradually to give the required flow condition. In the case of varying discharges, an automatic control device was attached to the regulating valve so that a predetermined hydrograph would be simulated.

After every experiment, cross sections were measured at 30-centimeter intervals along the flume. By comparing these cross sections with the original one, the volume of sand scoured from the bed during the experiment at each section was obtained. In only a few of the experiments was sand fed into the flume at the upper end.

Data Appearing in Summary

Because these experiments were primarily a study of scour and, hence, were not considered applicable to the general problem of bed-load transportation and bed roughness, the basic data have not been summarized in this compilation of flume data.

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TABLE-27
BED-LOAD EXPERIMENTS OF G.K.GILBERT

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Slope of bed, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds' Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
							Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
								SAND A								
4A	1	2,633	20.12	1.98	0.0122		66.08		1.74	4.56	11,444	0.0112	114.8	1.19	5	–
"	2	2,633	"	—	0.0214		—		—	—	—	—	—	3.68	5	Antidunes
"	3	5,154	"	3.84	0.0069		66.72		3.08	4.56	20,475	0.0122	205.4	0.89	10	Smooth
"	4	5,154	"	2.90	0.0159		88.48		2.84	6.65	25,009	0.0132	250.8	4.77	4	Antidunes
"	5	15,433	"	8.29	0.0055		92.54		7.99	6.56	73,681	0.0148	739.0	2.88	5	Smooth
"	6	15,433	"	—	0.0107		—		—	—	—	—	—	7.80	3	Antidunes
"	7	5,154	30.48	3.60	0.0053		47.00		3.26	4.12	15,281	0.0158	153.3	0.31	10	Dunes
"	8	5,154	"	—	0.0204		—		—	—	—	—	—	5.09	3	Antidunes
"	9	10,279	"	5.33	0.0042		63.22		4.42	4.27	27,859	0.0128	279.4	0.62	8	Transition
"	10	10,279	"	—	0.0164		—		—	—	—	—	—	8.04	3	Antidunes
"	11	20,785	"	8.05	0.0044		84.73		7.83	5.81	66,170	0.0143	663.7	1.67	4	Smooth
"	12	20,785	"	—	0.0119		—		—	—	—	—	—	10.40	3	Antidunes
"	13	5,154	40.23	2.77	0.0063		46.18		2.62	4.02	12,068	0.0152	121.0	0.30	10	Dunes
"	14	"	"	2.56	0.0075		50.02		2.41	4.21	12,009	0.0145	120.5	0.45	10	"
"	15	"	"	2.29	0.0073		56.02		2.13	3.91	11,919	0.0118	119.6	0.42	10	"
"	16	"	"	2.44	0.0079		52.52		2.29	4.21	11,970	0.0137	120.1	0.52	8	"
"	17	"	"	1.92	0.0099		66.72		1.80	4.18	11,960	0.0102	120.0	0.94	6	Transition
"	18	"	"	1.77	0.0110	No Observations	72.45	No Observations	1.65	4.21	11,889	0.0094	119.3	1.27	5	Antidunes
"	19	"	"	1.86	0.0137		68.88		1.74	4.83	11,928	0.0114	119.6	1.69	5	"
"	20	"	"	1.83	0.0141		70.04		1.71	4.86	11,920	0.0112	119.6	1.81	5	"
"	21	"	"	—	0.0179		—		—	—	—	—	—	2.98	5	"
"	22	"	"	—	0.0186		—		—	—	—	—	—	3.36	3	"
"	23	10,279	40.23	5.82	0.0027		43.89		5.21	3.72	22,807	0.0165	228.8	0.22	8	Dunes
"	24	"	"	3.78	0.0051		67.60		3.32	4.08	22,390	0.0109	224.6	0.94	6	Transition
"	25	"	"	3.51	0.0058		72.88		3.05	4.16	22,148	0.0102	222.1	1.02	5	–
"	26	"	"	3.41	0.0067		74.83		3.02	4.45	22,516	0.0106	225.8	1.07	5	–
"	27	"	"	3.41	0.0084		74.83		3.23	5.16	24,106	0.0120	241.8	1.84	4	–
"	28	"	"	3.96	0.0090		64.47		3.66	5.68	23.512	0.0162	235.8	1.89	5	Transition
"	29	"	"	3.51	0.0118		72.88		3.23	6.11	23,478	0.0151	235.5	3.31	4	Antidunes
"	30	"	"	3.23	0.0114		79.07		2.96	5.75	23.311	00129	233.8	3.48	5	"
"	31	"	"	2.71	0.0143		94.18		2.47	5.88	23,183	0.0108	232.5	440	4	"
"	32	"	"	2.96	0.0155		86.41		2.74	6.46	23,631	0.0131	237.0	502	4	"
"	33	"	"	—	0.0165		—		—	—	—	—	—	5.97	4	"
"	34	20,785	40.23	8.14	0.0035		63.49		8.02	5.25	50,742	0.0173	508.9	0.94	5	Dunes
"	35	"	"	6.25	0.0048		82.66		6.13	5.37	50,487	0.0130	506.4	2.09	4	Smooth
"	36	"	"	6.04	0.0051		85.59		5.94	5.45	50,723	0.0127	508.9	2.21	4	"
"	37	"	"	5.79	0.0073		89.21		5.70	6.39	50,698	0.0142	508.5	3.88	4	Antidunes
"	38	"	"	—	0.0083		—		—	—	—	—	—	3.83	3	"
"	39	"	"	—	0.0081		—		—	—	—	—	—	4.77	3	"
"	40	"	"	—	0.0097		—		—	—	—	—	—	534	3	"
"	41	"	"	—	0.0095		—		—	—	—	—	—	5.97	3	"
"	42	"	"	—	0.0113		—		—	—	—	—	—	8.13	3	"
"	43	"	"	—	0.0124		—		—	—	—	—	—	9.07	3	"
"	44	10,279	59.74	5.46	0.0036		31.55		5.27	4.31	16,586	0.0267	166.4	0.15	6	Dunes
"	45	"	"	3.60	0.0041		47.85		3.38	3.69	16.140	0.0140	161.9	0.33	6	–
"	46	"	"	3.60	0.0055		47.85		3.41	4.29	16.287	0.0164	163.4	0.35	6	–
"	47	"	"	3.14	0.0060		54.80		2.96	4.17	16,156	0.0135	162.0	0.54	5	–
"	48	"	"	2.74	0.0078		62.73		2.59	4.45	16,204	0.0123	162.5	1.00	5	–
"	49	"	"	2.50	0.0094		68.85		2.35	4.65	16,111	0.0116	161.6	1.54	5	Antidunes
"	50	"	"	2.23	0.0110		77.33		2.10	4.76	16,213	0.0103	162.6	2.13	5	"
"	51	"	"	2.35	0.0117		73.30		2.23	5.05	16,260	0.0115	163.1	2.14	5	"
"	52	"	"	2.29	0.0118		75.26		2.16	5.00	16,237	0.0112	162.9	2.41	4	"
"	53	"	"	2.19	0.0138		78.39		207	5.30	16,201	0.0113	162.5	3.00	4	"
"	54	"	"	2.32	0.0150		74.28		2.23	5.72	16,478	0.0131	165.3	3.23	4	"
"	55	"	"	2.04	0.0159		84.25		1.95	5.52	16,388	0.0109	164.4	3.65	4	"
"	56	"	"	2.10	0.0173		81.81		2.01	5.84	16,411	0.0119	164.6	4.42	3	"
"	57	"	"	2.13	0.0177		80.65		2.04	5.95	16,420	0.0123	164.7	4.74	3	"
"	58	20,785	59.74	8.63	0.0018		40.33		7.89	3.73	31,742	0.0194	318.4	0.14	10	–
"	59	"	"	5.49	0.0036		63.40		4.94	4.18	31,213	0.0127	313.1	0.55	6	–
"	60	"	"	4.75	0.0045		73.18		4.27	4.34	31,133	0.0112	312.3	1.39	4	–
"	61	"	"	4.75	0.0049		73.18		4.30	4.54	31,359	0.0117	314.5	1.34	5	Smooth
"	62	"	"	4.18	0.0056		83.33		372	4.52	30,897	0.0100	309.9	1.76	5	"
"	63	"	"	4.33	0.0079		80.38		3.99	5.56	32,000	0.0129	321.0	2.73	4	Transition

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE —27 continued

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Slope of bed, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds' Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G(2) grams per second per centimeter	Duration of run minutes	Bed condition
							Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND A (cont.)																
4A	64	20,785	59.74	4.11	0.0075		84.55		3.75	5.25	31,603	0.0115	317.0	2.80	4	Transition
"	65	"	"	3.93	0.0094		88.48		3.63	5.78	31,996	0.0120	320.9	3.00	3	Antidunes
"	66	"	"	4.11	0.0098		84.55		3.81	6.05	32,118	0.0133	322.1	3.87	3	"
"	67	"	"	3.96	0.0101		87.81		3.66	6.02	32,025	0.0126	321.2	4.67	3	"
"	68	31,687	"	6.71	0.0045		79.10		5.91	5.11	46,632	0.0129	4677	1.52	4	Smooth
"	69	"	"	6.31	0.0039		84.06		5.40	4.54	45,214	0.0106	453.5	1.71	4	"
"	70	"	"	5.91	0.0057		89.70		5.21	5.40	46,612	0.0118	467.5	2.18	4	"
"	71	"	"	5.97	0.0059		88.79		5.30	5.54	46,953	0.0122	470.9	3.15	3	"
"	72	"	"	5.55	0.0063		95.62		4.88	5.49	46,495	0.0111	466.3	3.70	3	"
"	73	"	"	5.70	0.0060		93.06		5.00	5.42	46,382	0.0113	465.2	3.83	3	–
"	74	"	"	5.03	0.0081		105.46		4.45	5.95	46,790	0.0107	469.3	4.32	4	Transition
"	75	"	"	5.46	0.0079		97.20		4.88	6.15	47,262	0.0122	474.0	4.87	3	Antidunes
"	76	"	"	—	0.0095		—		—	—	—	—	—	5.71	3	"
"	77	"	"	5.36	0.0102		98.88		4.88	6.98	48,080	0.0137	482.2	5.79	3	"
SAND B																
4B	1	2,633	7.01	5.85	0.0085		64.19		3.20	5.17	20,480	0.0145	205.4	0.57	9	Transition
"	2	"	"	5.61	0.0094		67.00		3.08	5.33	20,561	0.0142	206.2	0.96	7	"
"	3	"	"	5.30	0.0101	No Observations	70.84	No Observations	2.84	5.30	20,023	0.0132	200.8	1.16	7	Smooth
"	4	"	"	4.45	0.0149		84.43		2.44	5.97	20,522	0.0122	205.8	2.85	7	"
"	5	"	"	—	0.0212		—		—	—	—	—	—	4.71	7	Antidunes
"	6	5,154	7.01	11.09	0.0073		66.26		5.18	6.09	34,233	0.0179	343.4	0.57	10	Dunes
"	7	"	"	8.66	0.0112		84.92		3.78	6.44	32,004	0.0141	321.0	2.57	6	Smooth
"	8	"	"	7.01	0.0155		104.85		2.77	6.49	28,998	0.0109	290.9	4.42	5	Transition
"	9	"	"	7.07	0.0155		103.97		2.87	6.60	29,698	0.0112	297.9	4.56	7	"
"	10	2,633	13.41	4.15	0.0075		47.37		3.44	4.97	16,265	0.0191	163.1	0.40	6	Dunes
"	11	"	"	3.35	0.0090		58.55		2.68	4.87	15,656	0.0146	157.0	0.82	7	Smooth
"	12	"	"	2.83	0.0118		69.28		2.26	5.11	15,583	0.0125	156.3	1.34	4	Transition
"	13	"	"	2.13	0.0162		92.02		1.59	5.02	14,541	0.0087	145.9	2.54	7	Antidunes
"	14	"	"	2.19	0.0231		89.49		1.80	6.38	16,042	0.0117	160.9	3.95	5	"
"	15	"	"	2.07	0.0238		94.73		1.68	6.25	15,830	0.0107	158.8	4.77	4	"
"	16	5,154	13.41	5.91	0.0050		64.98		3.78	4.31	24,489	0.0123	245.6	0.63	7	Transition
"	17	"	"	5.39	0.0075		71.23		3.75	5.25	26,624	0.0136	267.0	1.19	5	Smooth
"	18	"	"	4.45	0.0098		86.35		2.96	5.33	25,458	0.0110	255.3	2.01	6	Transition
"	19	"	"	—	0.0166		—		—	—	—	—	—	5.44	8	Antidunes
"	20	"	"	4.24	0.0173		90.71		3.23	7.40	29,220	0.0147	293.1	5.67	4	"
"	21	2,633	20.12	2.71	0.0075		48.25		2.41	4.21	11,584	0.0150	116.2	0.25	8	Dunes
"	22	"	"	2.44	0.0084		53.68		2.13	4.19	11,421	0.0132	114.6	0.46	6	"
"	23	"	"	1.83	0.0123		71.57		1.59	4.37	11,310	0.0098	113.4	0.84	7	Smooth
"	24	"	"	1.80	0.0132		72.79		1.55	4.49	11,278	0.0098	113.1	0.75	9	Transition
"	25	"	"	1.77	0.0141		74.04		1.52	4.59	11,250	0.0099	112.8	1.09	5	"
"	26	"	"	1.52	0.0147		85.89		1.28	4.30	10,961	0.0077	109.9	1.39	5	"
"	27	"	"	1.71	0.0163		76.69		1.49	4.89	11,423	0.0101	114.6	1.69	5	"
"	28	"	"	1.65	0.0201		79.52		1.46	5.37	11,599	0.0107	116.3	2.04	5	"
"	29	"	"	1.49	0.0209		87.66		1.31	5.18	11,458	0.0092	114.9	2.63	5	Antidunes
"	30	"	"	1.77	0.0217		74.04		1.59	5.81	11,700	0.0125	117.4	2.83	5	"
"	31	"	"	1.13	0.0296		116.07		0.95	5.24	10,936	0.0066	109.7	4.62	7	"
"	32	5,154	20.12	5.33	0.0035		48.04		4.27	3.83	20,438	0.0150	205.0	0.21	8	Dunes
"	33	"	"	5.33	0.0036		48.04		4.30	3.90	20,586	0.0153	206.5	0.30	8	"
"	34	"	"	—	0.0069		—		—	—	—	—	—	0.60	7	–
"	35	"	"	4.18	0.0068		61.36		3.44	4.79	21,069	0.0142	211.3	0.80	6	–
"	36	"	"	3.44	0.0066		74.37		2.62	4.12	19,434	0.0097	194.9	0.99	8	–
"	37	"	"	3.35	0.0072		76.41		2.56	4.25	19,502	0.0097	195.6	1.04	4	–
"	38	"	"	3.26	0.0081		78.55		2.53	4.48	19,814	0.0099	198.7	0.94	8	Smooth
"	39	"	"	3.44	0.0098		74.37		2.84	5.22	21,021	0.0124	210.8	2.09	7	–
"	40	"	"	3.08	0.0106		83.21		2.47	5.07	20,484	0.0105	205.5	1.94	6	–
"	41	"	"	—	0.0118		—		—	—	—	—	—	2.19	9	–
"	42	"	"	3.41	0.0117		75.04		2.87	5.73	21,435	0.0135	215.0	2.34	8	–
"	43	"	"	3.26	0.0132		78.55		2.77	5.99	21,725	0.0134	217.9	2.73	5	Transition
"	44	"	"	—	0.0135		—		—	—	—	—	-	2.73	8	–
"	45	"	"	3.14	0.0136		81.59		2.65	5.95	21,573	0.0127	216.4	2.73	5	Transition
"	46	"	"	—	0.0151		—		—	—	—	—	—	3.33	7	Antidunes
"	47	"	"	—	0.0154		—		—	—	—	—	—	3.58	7	"
"	48	"	"	2.77	0.0151		92.35		2.29	5.82	21,048	0.0107	211.1	4.37	4	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE—27 (cont.)

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Slope of bed, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds' Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
							Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
								SAND B (cont.)								
4B	49	5,154	20.12	2.50	0.0200	No Observations	102.50	No Observations	2.07	6.38	21,184	0.0104	212.5	5.22	5	Antidunes
"	50	"	"	2.53	0.0188		101.25		2.10	6.23	21,229	0.0103	212.9	5.57	6	"
"	51	"	"	2.35	0.0205		109.15		1.92	6.21	20,894	0.0094	209.6	5.91	6	"
"	52	"	"	—	0.0224		—		—	—	—	—	—	6.26	4	"
"	53	"	"	3.51	0.0219		73.09		3.17	8.25	23,101	0.0203	231.7	6.91	5	"
"	54	"	"	2.93	0.0246		87.54		2.59	7.91	22,614	0.0157	226.8	7.90	5	"
"	55	"	"	2.50	0.0279		102.50		2.16	7.69	22,115	0.0127	221.8	8.40	5	"
"	56	"	"	—	0.0314		—		—	—	—	—	—	10.59	4	"
"	57	"	"	—	0.0306		—		—	—	—	—	—	11.73	3	"
"	58	"	"	—	0.0291		—		—	—	—	—	—	12.62	3	"
"	59	"	"	—	0.0293		—		—	—	—	—	—	13.32	4	"
"	60	"	"	—	0.0403		—		—	—	—	—	—	18.74	3	"
"	61	10,279	20.12	6.58	0.0051		77.60		4.57	4.78	35,373	0.0118	354.8	1.44	5	Transition
"	62	"	"	6.46	0.0068		79.07		4.82	5.67	37,966	0.0138	380.8	1.99	8	"
"	63	"	"	6.25	0.0069		81.78		4.60	5.58	37,522	0.0130	376.4	1.94	6	"
"	64	"	"	6.16	0.0075		83.00		4.57	5.80	37,834	0.0133	379.5	2.44	6	Smooth
"	65	"	"	5.73	0.0080		89.18		4.18	5.72	37,131	0.0121	372.4	2.73	5	"
"	66	"	"	5.43	0.0098		94.18		4.05	6.24	38,067	0.0124	381.8	3.83	4	Transition
"	67	"	"	5.76	0.0099		88.70		4.45	6.57	39354	0.0141	394.7	4.52	5	Antidunes
"	68	"	"	5.82	0.0114		87.78		4.63	7.20	40,546	0.0157	406.7	5.17	5	"
"	69	"	"	5.39	0.0154		94.70		4.42	8.17	41,732	0.0164	418.6	7.36	4	"
"	70	"	"	4.72	0.0143		108.14		3.63	7.13	39,105	0.0121	392.2	7.55	5	"
"	71	"	"	—	0.0163		—		—	—	—	—	—	8.15	4	"
"	72	"	"	4.82	0.0166		106.10		3.84	7.91	40,620	0.0138	407.4	8.30	5	"
"	73	"	"	—	0.0171		—		—	—	—	—	—	9.24	3	"
"	74	"	"	—	0.0181		—		—	—	—	—	—	11.23	4	"
"	75	15,433	20.12	14.36	0.0021		53.43		9.42	4.40	50,169	0.0177	503.2	0.29	6	Dunes
"	76	"	"	11.19	0.0023		68.58		6.01	3.68	41,059	0.0108	411.8	0.80	9	"
"	77	"	"	8.87	0.0046		86.50		5.40	4.93	46,527	0.0112	466.7	1.74	5	Transition
"	78	"	"	8.90	0.0063		86.20		6.16	6.17	52,914	0.0144	530.7	2.68	8	"
"	79	"	"	7.86	0.0074		97.57		5.27	6.19	51,295	0.0124	514.5	3.38	6	"
"	80	"	"	7.92	0.0072		96.80		5.30	6.12	51,189	0.0124	513.4	4.03	6	Smooth
"	81	"	"	6.71	0.0087		114.39		4.24	6.01	48,322	0.0099	484.7	5.17	5	—
"	82	"	"	6.89	0.0089		111.37		4.48	6.25	49,756	0.0107	499.1	5.52	5	Transition
"	83	"	"	7.01	0.0100		109.42		4.82	6.87	52,539	0.0121	527.0	6.56	5	Antidunes
"	84	"	"	7.04	0.0132		108.97		5.27	8.26	57,288	0.0149	574.6	8.40	5	"
"	85	"	"	—	0.0181		—		—	—	—	—	—	12.03	3	"
"	86	"	"	—	0.0181		—		—	—	—	—	—	13.47	3	"
"	87	"	"	—	0.0179		—		—	—	—	—	—	15.11	3	"
"	88	5,154	30.48	3.23	0.0061		52.33		2.93	4.18	15,266	0.0141	153.1	0.36	5	Dunes
"	89	"	"	3.11	0.0061		54.38		2.77	4.07	15,040	0.0131	150.9	0.43	5	—
"	90	"	"	2.23	0.0097		75.99		1.95	4.31	14,782	0.0094	148.3	0.92	6	Transition
"	91	"	"	2.47	0.0115		68.49		2.26	5.04	15,405	0.0125	154.5	1.28	5	"
"	92	"	"	2.23	0.0129		75.99		2.01	5.05	15,243	0.0111	152.9	1.67	5	Smooth
"	93	"	"	1.83	0.0187		92.45		1.65	5.49	15,171	0.0096	152.2	3.22	4	Antidunes
"	94	"	"	2.04	0.0214		82.78		1.89	6.30	15,598	0.0125	156.5	3.81	4	"
"	95	"	"	2.01	0.0243		84.06		1.86	6.66	15,580	0.0130	156.3	5.15	3	"
"	96	"	"	2.13	0.0263		79.25		2.01	7.20	15,897	0.0152	159.5	5.97	4	"
"	97	10,279	30.48	14.48	0.00044		23.29		11.43	7.02	26,540	0.0212	266.2	0.00	—	Dunes forming
"	98	"	"	10.49	0.0016		32.16		9.11	3.78	29,223	0.0252	293.1	0.04	390	Dunes
"	99	"	"	9.78	0.0016		34.47		8.38	3.63	28,807	0.0222	288.9	0.05	360	"
"	100	"	"	—	0.0028		—		—	—	—	—	—	0.20	60	"
"	101	"	"	8.47	0.0031		39.81		7.56	4.79	30,002	0.0250	300.9	0.22	44	"
"	102	"	"	6.52	0.0023		51.69		5.21	3.43	26,860	0.0130	269.4	0.24	5	"
"	103	"	"	6.83	0.0033		49.41		5.85	4.35	28,829	0.0176	289.2	0.31	71	"
"	104	"	"	6.34	0.0029		53.19		5.21	3.85	27,640	0.0141	277.2	0.32	6	"
"	105	"	"	7.74	0.0031		43.56		6.80	4.55	29,519	0.0213	296.1	0.36	62	"
"	106	"	"	5.73	0.0043		58.86		4.85	4.52	28,439	0.0148	285.2	0.69	30	—
"	107	"	"	5.94	0.0049		56.75		5.15	4.98	29,145	0.0171	292.3	0.82	15	—
"	108	"	"	5.00	0.0054		67.45		4.21	4.72	28,284	0.0132	283.7	0.92	4	—
"	109	"	"	—	0.0063		—		—	—	—	—	—	1.61	8	Transition
"	110	"	"	4.69	0.0078		71.84		4.08	5.59	29,251	0.0146	293.4	1.51	4	Smooth
"	111	"	"	4.57	0.0065		73.76		3.84	4.95	28,239	0.0124	283.2	1.80	9	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE —27 (cont.)

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Slope of bed, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds' Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, $G^{(2)}$ grams per second per centimeter	Duration of run minutes	Bed condition
							Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND B (cont.)																
4B	112	10,279	30.48	3.66	0.0100		92.20		3.08	5.49	28,294	0.0107	283.8	2.59	4	Antidunes
"	113	"	"	3.26	0.0151		103.42		2.80	6.44	28,912	0.0110	290.0	5.02	4	"
"	114	"	"	3.93	0.0166		85.77		3.54	7.59	30,237	0.0162	303.3	6.76	4	"
"	115	"	"	3.41	0.0178		98.79		3.02	7.26	29,726	0.0131	298.2	7.15	3	"
"	116	"	"	—	0.0200		—		—	—	—	—	—	8.79	3	"
"	117	"	"	—	0.0214		—		—	—	—	—	—	10.01	3	"
"	118	"	"	—	0.0228		—		—	—	—	—	—	11.38	3	"
"	119	15,433	30.48	5.91	0.0079		85.62		4.91	6.17	41,888	0.0139	420.1	3.51	5	Smooth
"	120	"	"	5.09	0.0083		99.46		4.05	5.74	40,200	0.0108	403.2	3.84	5	Transition
"	121	"	"	4.79	0.0116		105.80		3.96	6.71	41,793	0.0119	419.2	5.48	4	Antidunes
"	122	"	"	5.15	0.0131		98.30		4.42	7.54	43,319	0.0146	434.5	6.53	3	"
"	123	"	"	—	0.0129		—		—	—	—	—	—	7.19	3	"
"	124	"	"	—	0.0146		—		—	—	—	—	—	8.99	3	"
"	125	"	"	4.39	0.0163		115.37		3.72	7.71	42,778	0.0123	429.1	10.04	3	"
"	126	"	"	—	0.0165		—		—	—	—	—	—	10.33	3	"
"	127	"	"	—	0.0184		—		—	—	—	—	—	12.99	2	"
"	128	"	"	—	0.0210		—		—	—	—	—	—	16.54	2	"
"	129	20,785	30.48	22.40	0.00012	No Observations	30.45	No Observations	3.72	0.66	11,290	0.0401	113.2	0.0	—	Dunes forming
"	130	"	"	15.15	0.0015		45.02		11.74	4.16	52,673	0.0207	528.3	0.15	60	—
"	131	"	"	15.12	0.0018		45.11		12.13	4.63	54,559	0.0231	547.2	0.16	90	—
"	132	"	"	10.12	0.0026		67.39		7.35	4.33	49,357	0.0133	495.1	0.56	20	—
"	133	"	"	8.60	0.0038		79.34		6.34	4.86	50,152	0.0124	503.0	1.25	10	—
"	134	"	"	7.83	0.0048		87.05		5.85	5.25	50,790	0.0120	509.4	1.71	10	—
"	135	"	"	7.83	0.0045		87.05		5.76	5.04	50,000	0.0115	501.5	1.77	8	Transition
"	136	"	"	7.83	0.0050		87.05		5.91	5.38	51,319	0.0123	514.7	1.94	10	—
"	137	"	"	7.99	0.0053		85.40		6.16	5.66	52,424	0.0133	525.8	1.97	7	Transition
"	138	"	"	7.83	0.0044		87.05		5.73	4.97	49,731	0.0113	498.8	2.03	9	"
"	139	"	"	7.62	0.0054		89.49		5.79	5.54	51,669	0.0123	518.2	2.62	5	—
"	140	"	"	7.22	0.0068		94.40		5.64	6.13	53,073	0.0129	532.3	3.35	5	Transition
"	141	"	"	6.31	0.0092		108.08		4.97	6.70	53,533	0.0120	536.9	6.17	5	Smooth
"	142	"	"	—	0.0116		—		—	—	—	—	—	8.01	3	Antidunes
"	143	"	"	—	0.0130		—		—	—	—	—	—	10.01	3	"
"	144	"	"	—	0.0146		—		—	—	—	—	—	12.14	2	"
"	145	"	"	—	0.0172		—		—	—	—	—	—	13.65	2	"
"	146	"	"	—	0.0156		—		—	—	—	—	—	14.21	2	"
"	147	5,154	40.23	3.93	0.0040		32.58		3.75	3.84	12,177	0.0217	122.1	0.13	8	Dunes
"	148	"	"	—	0.0045		—		—	—	—	—	—	0.13	8	"
"	149	"	"	2.47	0.0080		51.91		2.32	4.26	11,986	0.0140	120.2	0.35	6	"
"	150	"	"	1.86	0.0098		68.88		1.71	4.05	11,723	0.0095	117.6	0.42	6	"
"	151	"	"	1.92	0.0112		66.72		1.83	4.48	12,167	0.0110	122.0	0.85	6	Transition
"	152	"	"	1.74	0.0118		73.73		1.62	4.32	11,871	0.0094	119.1	0.67	9	"
"	153	"	"	1.71	0.0122		75.04		1.59	4.36	11,858	0.0093	118.9	1.07	6	Smooth
"	154	"	"	1.62	0.0141		79.28		1.49	4.55	11,809	0.0091	118.4	1.39	6	Transition
"	155	"	"	1.25	0.0166		102.50		1.13	4.29	11,527	0.0063	115.6	1.69	6	"
"	156	"	"	1.55	0.0171		82.42		1.46	4.95	12,022	0.0095	120.6	2.01	5	"
"	157	"	"	1.16	0.0177		110.58		1.04	4.24	11,422	0.0057	114.6	1.99	5	"
"	158	"	"	1.37	0.0188		93.39		1.28	4.86	11,918	0.0081	119.5	2.31	7	Antidunes
"	159	"	"	1.77	0.0211		72.45		1.68	5.89	12,107	0.0131	121.4	2.86	4	"
"	160	"	"	—	0.0233		—		—	—	—	—	—	3.16	4	"
"	161	"	"	1.13	0.0232		113.57		1.04	4.86	11,731	0.0064	117.7	3.53	4	"
"	162	"	"	1.19	0.0246		107.75		1.10	5.14	11,785	0.0072	118.2	3.78	4	"
"	163	10,279	40.23	6.92	0.0025		36.94		6.31	3.93	23,235	0.0214	233.1	0.13	5	Dunes
"	164	"	"	6.19	0.0026		41.27		5.58	3.77	22,951	0.0180	230.2	0.20	9	"
"	165	"	"	4.66	0.0043		54.77		4.18	4.20	22,804	0.0144	228.7	0.42	9	"
"	166	"	"	4.48	0.0043		57.03		3.99	4.10	22,704	0.0134	227.7	0.40	9	"
"	167	"	"	3.99	0.0047		63.98		3.51	4.02	22,358	0.0115	224.3	0.55	6	"
"	168	"	"	3.90	0.0066		65.47		3.51	4.76	22,878	0.0133	229.5	0.55	6	"
"	169	"	"	3.78	0.0069		67.57		3.41	4.81	22,999	0.0129	230.7	0.62	4	"
"	170	"	"	3.32	0.0082		76.90		2.96	4.88	22,671	0.0113	227.4	0.94	6	"
"	171	"	"	2.99	0.0107		85.50		2.68	5.31	22,862	0.0109	229.3	2.21	7	—
"	172	"	"	3.02	0.0120		84.64		2.74	5.68	23,148	0.0118	232.2	2.59	6	—
"	173	"		2.44	0.0128		104.79		2.13	5.18	22,295	0.0083	223.6	3.38	5	Antidunes
"	174	"	"	2.19	0.0133		116.40		1.89	4.97	21,934	0.0074	220.0	3.26	5	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Slope of bed, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds' Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
							Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND B (cont.)																
4B	175	10,279	40.23	2.99	0.0137		85.50		2.74	6.07	23,383	0.0125	234.5	3.33	5	Antidunes
"	176	"	"	2.80	0.0154		91.14		2.56	6.22	23,262	0.0119	233.3	4.03	7	"
"	177	"	"	2.50	0.0163		102.26		2.26	6.01	23,001	0.0100	230.7	4.30	5	"
"	178	"	"	—	0.0190		—		—	—	—	—	—	6.39	3	"
"	179	"	"	—	0.0212		—		—	—	—	—	—	6.49	3	"
"	180	15,433	40.23	6.28	0.0047		61.08		5.58	5.07	33,968	0.0164	340.7	0.72	5	Dunes
"	181	"	"	4.94	0.0054		77.69		4.21	4.72	32,578	0.0115	326.8	1.37	4	"
"	182	"	"	4.69	0.0061		81.72		4.02	4.91	32,778	0.0112	328.8	1.34	4	"
"	183	"	"	4.24	0.0076		90.53		3.63	5.20	32,737	0.0106	328.4	2.21	4	—
"	184	"	"	4.30	0.0076		89.28		3.69	5.24	32,828	0.0109	329.3	2.29	5	Smooth
"	185	"	"	4.51	0.0075		85.01		3.90	5.36	33,063	0.0117	331.6	2.61	5	"
"	186	"	"	4.82	0.0084		79.64		4.30	5.95	34,127	0.0141	342.3	2.59	4	Transition
"	187	"	"	4.30	0.0098		89.28		3.81	6.05	33,914	0.0126	340.2	3.65	4	Antidunes
"	188	"	"	3.23	0.0128		118.75		2.77	5.90	32,842	0.0087	329.4	5.42	3	"
"	189	"	"	—	0.0149		—		—	—	—	—	—	6.56	4	"
"	190	"	"	—	0.0149		—		—	—	—	—	—	6.91	3	"
"	191	"	"	—	0.0185		—		—	—	—	—	—	8.97	3	"
"	192	20,785	40.23	8.81	0.0031	No Observations	58.64	No Observations	7.53	4.78	44,018	0.0170	441.5	0.75	5	—
"	193	"	"	6.89	0.0041		75.01		5.70	4.79	42,628	0.0127	427.6	0.97	7	Transition
"	194	"	"	6.68	0.0050		77.39		5.64	5.26	43,509	0.0134	436.4	1.37	6	"
"	195	"	"	5.94	0.0050		86.93		4.85	4.87	42,000	0.0108	421.3	1.39	6	"
"	196	"	"	6.28	0.0053		82.30		5.24	5.22	43,021	0.0124	431.5	1.57	5	"
"	197	"	"	6.07	0.0058		85.16		5.09	5.38	43,216	0.0123	433.5	2.24	5	Smooth
"	198	"	"	5.30	0.0087		97.38		4.54	6.23	44,098	0.0122	442.3	3.21	6	"
"	199	"	"	5.18	0.0067		99.70		4.24	5.28	42,117	0.0100	422.4	3.38	6	"
"	200	"	"	5.24	0.0078		98.54		4.39	5.79	43,120	0.0112	432.5	3.33	5	"
"	201	"	"	5.03	0.0085		102.72		4.24	5.94	43,392	0.0110	435.2	3.58	4	Transition
"	202	"	"	5.27	0.0090		97.96		4.51	6.31	44,058	0.0123	441.9	4.15	4	"
"	203	"	"	5.15	0.0096		100.28		4.42	6.45	44,191	0.0122	443.2	4.42	5	Antidunes
"	204	"	"	5.06	0.0092		102.11		4.30	6.23	43,756	0.0115	438.9	4.52	5	"
"	205	"	"	—	0.0101		—		—	—	—	—	—	5.07	4	"
"	206	"	"	—	0.0110		—		—	—	—	—	—	6.34	3	"
"	207	"	"	—	0.0114		—		—	—	—	—	—	6.66	3	"
"	208	"	"	—	0.0117		—		—	—	—	—	—	6.96	3	"
"	209	"	"	—	0.0135		—		—	—	—	—	—	8.48	3	"
"	210	"	"	—	0.0145		—		—	—		—	—	8.50	3	"
"	211	"	"	—	0.0151		—		—	—	—	—	—	952	2	"
"	212	"	"	—	0.0165		—		—	—	—	—	—	12.06	2	"
"	213	"	"	—	0.0166		—		—	—	—	—	—	12.83	3	"
"	214	10,279	59.74	4.94	0.0031		34.84		4.72	3.79	16,409	0.0209	164.6	0.13	8	Dunes
"	215	"	"	3.17	0.0065		54.28		3.02	4.39	16,333	0.0144	163.8	0.30	8	—
"	216	"	"	3.35	0.0062		51.33		3.20	4.41	16,377	0.0155	164.3	0.42	12	—
"	217	"	"	2.13	0.0059		80.65		1.92	3.33	15,439	0.0068	154.9	0.60	23	—
"	218	"	"	2.65	0.0077		64.89		2.50	4.34	16,167	0.0116	162.2	0.67	12	—
"	219	"	"	2.44	0.0092		70.56		2.29	4.54	16,082	0.0110	161.3	0.74	8	Smooth
"	220	"	"	1.80	0.0101		95.71		1.65	4.04	15,707	0.0068	157.5	0.99	4	Transition
"	221	"	"	2.07	0.0103		83.00		1.92	4.40	15,888	0.0088	159.4	1.10	8	—
"	222	"	"	2.38	0.0107		72.36		2.26	4.87	16,275	0.0114	163.2	1.14	6	Transition
"	223	"	"	1.89	0.0121		91.07		1.77	4.58	16,053	0.0082	161.0	1.61	5	"
"	224	"	"	1.92	0.0145		89.58		1.80	5.06	16,058	0.0092	161.1	2.29	3	Antidunes
"	225	"	"	1.34	0.0148		128.29		1.22	4.21	15,592	0.0050	156.4	2.46	3	"
"	226	"	"	1.52	0.0162		112.90		1.40	4.72	15,782	0.0066	158.3	2.96	3	"
"	227	"	"	—	0.0164		—		—	—	—	—	—	3.11	3	"
"	228	"	"	—	0.0181		—		—	—	—	—	—	3.58	3	"
"	229	"	"	1.83	0.0200		94.09		1.74	5.84	16,294	0.0100	163.4	4.17	3	"
"	230	15,433	59.74	4.02	0.0054		64.22		3.72	4.44	23,812	0.0128	238.8	0.89	23	—
"	231	"	"	3.87	0.0070		66.75		3.63	4.99	24,138	0.0137	242.1	0.99	6	Smooth
"	232	"	"	3.96	0.0069		65.20		3.72	5.02	24,175	0.0142	242.5	1.17	5	—
"	233	"	"	3.84	0.0071		67.24		3.60	5.00	24,114	0.0137	241.9	1.21	18	—
"	234	"	"	2.77	0.0078		93.12		2.50	4.37	23,201	0.0081	232.7	1.51	3	—
"	235	"	"	3.38	0.0080		76.35		3.14	4.96	23,894	0.0117	239.7	1.49	5	Transition
"	236	"	"	3.51	0.0098		73.70		3.29	5.63	24,189	0.0138	242.6	1.57	4	"
"	237	"	"	—	0.0097		—		—	—	—	—	—	1.77	4	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE — 27(cont.)

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Slope of bed, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds' Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, $G^{(2)}$ grams per second per centimeter	Duration of run minutes	Bed condition
							Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND B (cont.)																
4B	238	15,433	59.74	3.02	0.0112	No Observations	85.62	No Observations	2.80	5.55	23,936	0.0114	240.1	2.41	4	Transition
"	239	"	"	—	0.0139		—		—	—	—	—	—	3.63	4	—
"	240	"	"	2.90	0.0160		89.21		2.74	6.56	24,397	0.0129	244.7	4.42	3	Antidunes
"	241	"	"	—	0.0158		—		—	—	—	—	—	5.01	3	"
"	242	"	"	—	0.0154		—		—	—	—	—	—	5.14	3	"
"	243	"	"	—	0.0161		—		—	—	—	—	—	5.07	3	"
"	244	"	"	—	0.0173		—		—	—	—	—	—	5.96	3	"
"	245	20,785	59.74	7.62	0.0023		45.66		6.98	3.97	31,776	0.0178	318.7	0.13	6	Dunes
"	246	"	"	5.73	0.0027		60.72		5.06	3.66	30,632	0.0117	307.2	0.67	5	—
"	247	"	"	5.21	0.0044		66.75		4.72	4.52	31,439	0.0130	315.3	0.67	8	—
"	248	"	"	4.91	0.0053		70.90		4.48	4.83	31,675	0.0130	317.7	1.10	8	—
"	249	"	"	—	0.0059		—		—	—	—		—	1.47	4	—
"	250	"	"	4.24	0.0064		82.14		3.84	4.91	31,448	0.0111	315.4	1.64	9	—
"	251	"	"	4.51	0.0056		77.11		4.08	4.74	31,398	0.0115	314.9	1.72	6	—
"	252	"	"	—	0.0080		—		—	—	—	—	—	3.11	3	Antidunes
"	253	"	"	—	0.0105		—		—	—	—	—	—	3.10	3	"
"	254	"	"	—	0.0103		—		—	—	—	—	—	3.31	3	"
"	255	"	"	4.57	0.0105		76.11		4.30	6.65	32,614	0.0165	327.1	4.00	4	"
"	256	"	"	—	0.0140		—		—	—	—	—	—	5.56	3	"
"	257	"	"	4.45	0.0139		78.18		4.24	7.60	33,026	0.0183	331.3	5.71	3	"
"	258	"	"	—	0.0138		—		—	—	—	—	—	5.89	3	"
"	259	"	"	3.78	0.0145		92.08		3.54	7.09	32,462	0.0141	325.6	5.83	3	"
"	260	"	"	—	0.0164		—		—	—	—	—	—	7.85	2	"
"	261	"	"	—	0.0187		—		—	—	—	—	—	8.70	2	"
"	262	31,687	59.74	12.53	0.0019		42.34		11.43	4.62	48,250	0.0243	484.0	0.11	10	Dunes
"	263	"	"	10.76	0.0018		49.29		9.51	4.10	46,735	0.0179	468.8	0.22	10	"
"	264	"	"	10.52	0.0032		50.44		9.69	5.52	48,745	0.0237	488.9	0.54	11	"
"	265	"	"	6.98	0.0028		75.99		5.88	4.02	44,571	0.0105	447.1	0.99	4	Transition
"	266	"	"	9.60	0.0059		55.23		9.05	7.24	49,850	0.0281	500.0	1.82	8	—
"	267	"	"	6.43	0.0061		82.48		5.79	5.89	47,621	0.0142	477.6	1.84	6	Smooth
"	268	"	"	5.73	0.0065		92.57		5.09	5.70	46,977	0.0120	471.2	2.16	5	"
"	269	"	"	5.73	0.0072		92.57		5.12	6.01	47,263	0.0127	474.1	3.20	4	"
"	270	"	"	5.61	0.0073		94.58		5.00	5.98	47,140	0.0122	472.8	3.85	4	—
"	271	"	"	5.70	0.0091		93.06		5.21	6.82	48,358	0.0143	485.0	5.31	3	Transition
"	272	"	"	5.36	0.0100		98.85		4.88	6.92	48,065	0.0135	482.1	5.19	2	—
"	273	"	"	—	0.0093		—		—	—	—	—	—	5.96	2	—
"	274	"	"	—	0.0098		—		—	—	—	—	—	5.94	2	—
"	275	"	"	—	0.0113		—		—	—	—	—	—	6.80	3	—
"	276	"	"	4.42	0.0131		120.00		3.99	7.16	47,773	0.0112	479.2	7.00	3	Antidunes
SAND C																
4C	1	2,633	13.41	4.91	0.0064		40.02		4.21	5.14	16,782	0.0242	168.3	0.24	7	Dunes
"	2	"	"	4.30	0.0085		45.69		3.69	5.54	16,800	0.0224	168.5	0.40	5	Transition
"	3	"	"	3.99	0.0094		49.16		3.41	5.61	16,733	0.0207	167.8	0.70	5	Smooth
"	4	"	"	3.72	0.0101		52.79		3.14	5.58	16,521	0.0189	165.7	0.89	5	"
"	5	"	"	3.57	0.0126		55.08		3.08	6.17	16,903	0.0200	169.5	1.42	7	"
"	6	"	"	3.38	0.0145		58.03		2.93	6.45	16,929	0.0197	169.8	1.94	4	"
"	7	"	"	3.38	0.0159		58.03		2.96	6.79	17,108	0.0208	171.6	2.61	5	"
"	8	"	"	3.05	0.0171		64.43		2.62	6.63	16,836	0.0179	168.9	2.54	4	"
"	9	"	"	—	0.0274		—		—	—	—	—	—	3.43	4	Antidunes
"	10	5,154	13.41	7.16	0.0061		53.64		5.49	5.73	29,140	0.0211	292.3	0.72	6	Dunes
"	11	"	"	7.10	0.0070		54.13		5.61	6.20	30,265	0.0226	303.6	1.04	6	Transition
"	12	"	"	5.12	0.0133		75.04		4.02	7.24	30,099	0.0180	301.9	2.83	6	Smooth
"	13	"	"	5.36	0.0132		71.63		4.30	7.46	30,695	0.0197	307.9	3.21	5	"
"	14	"	"	5.24	0.0138		73.30		4.18	7.52	30,518	0.0193	306.1	3.50	4	"
"	15	"	"	4.66	0.0152		82.42		3.63	7.35	29,805	0.0164	298.9	3.80	5	"
"	16	"	"	4.21	0.0216		91.35		3.35	8.43	30,538	0.0167	306.3	7.23	3	Antidunes
"	17	2,633	20.12	3.29	0.0054		39.78		2.93	3.94	11,605	0.0175	116.4	0.17	10	Dunes
"	18	"	"	2.56	0.0079		51.11		2.26	4.18	11,496	0.0139	115.3	0.43	13	"
"	19	"	"	2.35	0.0098		55.78		2.07	4.46	11,528	0.0134	115.6	0.50	7	"
"	20	"	"	2.38	0.0097		55.08		2.10	4.47	11,548	0.0136	115.8	0.75	6	"
"	21	"	"	2.29	0.0105		57.27		2.01	4.55	11,489	0.0132	115.2	0.75	6	"
"	22	"	"	2.35	0.0105		55.78		2.10	4.65	11,696	0.0140	117.3	0.84	6	"
"	23	"	"	2.23	0.0111		58.83		1.98	4.64	11,619	0.0131	116.5	0.80	6	Transition

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE —27(cont.)

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Slope of bed, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds' Number, R	Manning's n of bed, n_b [(1)]	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G [(2)] grams per second per centimeter	Duration of run minutes	Bed condition
							Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND C (cont.)																
4C	24	2,633	20.12	2.01	0.0136		65.07		1.80	4.90	11,665	0.0123	117.0	1.09	6	Smooth
"	25	"	"	1.92	0.0156		68.18		1.71	5.11	11,603	0.0122	116.4	1.74	5	"
"	26	"	"	1.68	0.0198		78.09		1.49	5.39	11,632	0.0109	116.7	2.39	4	Antidunes
"	27	"	"	1.52	0.0238		85.89		1.34	5.59	11,484	0.0101	115.2	3.03	4	"
"	28	"	"	1.58	0.0252		82.60		1.43	5.95	11,802	0.0113	118.4	3.68	3	"
"	29	"	"	—	0.0302		—		—	—	—	—	—	4.97	3	"
"	30	"	"	—	0.0341		—		—	—	—	—	—	5.42	5	"
"	31	"	"	—	0.0373		—		—	—	—	—	—	7.06	3	"
"	32	"	"	—	0.0379		—		—	—	—	—	—	7.26	3	"
"	33	"	"	—	0.0404		—		—	—	—	—	—	7.75	3	"
"	34	5,154	20.12	7.38	0.0024		34.75		6.19	3.82	21,436	0.0220	215.0	0.11	420	Dunes
"	35	"	"	4.15	0.0054		61.81		3.26	4.16	20,096	0.0121	201.6	0.48	11	"
"	36	"	"	3.78	0.0064		67.79		2.99	4.33	20,188	0.0114	202.5	0.80	8	"
"	37	"	"	4.02	0.0076		63.67		3.35	5.00	21,285	0.0142	213.5	0.89	7	"
"	38	"	"	3.87	0.0072		66.17		3.14	4.71	20,709	0.0128	207.7	0.89	7	"
"	39	"	"	3.57	0.0094		71.84		2.96	5.22	21,179	0.0129	212.4	1.39	6	Transition
"	40	"	"	2.93	0.0116		87.54		2.35	5.17	20,485	0.0101	205.5	1.94	5	Smooth
"	41	"	"	3.02	0.0117	No Observations	84.89	No Observations	2.44	5.29	20,634	0.0107	207.0	2.24	7	"
"	42	"	"	—	0.0154		—		—	—	—	—	—	3.58	5	"
"	43	"	"	2.71	0.0157		94.43		2.23	5.85	20,948	0.0105	210.1	3.88	8	"
"	44	"	"	—	0.0195		—		—	—	—	—	—	5.22	4	Transition
"	45	"	"	1.89	0.0224		135.58		1.43	5.61	19,371	0.0065	194.3	5.62	4	Antidunes
"	46	"	"	—	0.0232		—		—	—	—	—	—	6.11	4	"
"	47	"	"	—	0.0233		—		—	—	—	—	—	6.61	4	"
"	48	"	"	—	0.0258		—		—	—	—	—	—	7.26	3	"
"	49	"	"	—	0.0254		—		—	—	—	—	—	7.70	4	"
"	50	"	"	—	0.0263		—		—	—	—	—	—	8.10	3	"
"	51	"	"	—	0.0282		—		—	—	—	—	—	9.44	4	"
"	52	"	"	—	0.0299		—		—	—	—	—	—	10.19	3	"
"	53	"	"	—	0.0305		—		—	—	—	—	—	10.93	3	"
"	54	"	"	—	0.0320		—		—	—	—	—	—	10.79	3	"
"	55	"	"	—	0.0345		—		—	—	—	—	—	12.23	3	"
"	56	10,279	20.12	7.35	0.0044		69.56		5.21	4.74	36,147	0.0133	362.6	1.09	5	Dunes
"	57	"	"	6.77	0.0064		75.53		5.09	5.65	38,330	0.0145	384.5	1.59	5	Transition
"	58	"	"	6.43	0.0070		79.43		4.82	5.75	38,139	0.0139	382.5	1.69	6	"
"	59	"	"	6.49	0.0061		78.70		4.69	5.30	36,832	0.0129	369.4	1.84	4	"
"	60	"	"	6.58	0.0063		77.60		4.85	5.47	37,493	0.0136	376.1	1.74	4	"
"	61	"	"	6.46	0.0066		79.10		4.79	5.57	37,736	0.0136	378.5	1.99	4	"
"	62	"	"	6.25	0.0067		81.78		4.54	5.46	37,033	0.0128	371.4	1.94	5	"
"	63	"	"	5.67	0.0087		90.10		4.21	5.99	37,783	0.0125	379.0	2.68	5	Smooth
"	64	"	"	5.30	0.0099		96.38		3.93	6.18	37,784	0.0119	379.0	3.88	6	"
"	65	"	"	5.09	0.0104		100.40		3.75	6.18	37,527	0.0114	376.4	4.13	5	"
"	66	"	"	5.12	0.0108		99.76		3.81	6.35	37,895	0.0118	380.1	4.87	3	Transition
"	67	"	"	5.27	0.0107		96.90		3.96	6.45	38,277	0.0124	383.9	4.92	3	—
"	68	"	"	5.00	0.0108		102.26		3.66	6.22	37,295	0.0112	374.1	4.82	3	—
"	69	"	"	5.30	0.0119		96.38		4.12	6.93	39,541	0.0135	396.6	6.01	5	Smooth
"	70	"	"	5.12	0.0123		99.76		3.93	6.89	39,109	00128	392.3	6.01	4	"
"	71	"	"	4.91	0.0141		104.09		3.81	7.26	39,539	0.0129	396.6	6.66	4	Transition
"	72	"	"	—	0.0171		—		—	—	—	—	—	8.00	3	Antidunes
"	73	"	"	—	0.0187		—		—	—	—	—	—	9.05	3	"
"	74	"	"	—	0.0191		—		—	—	—	—	—	9.10	3	"
"	75	"	"	—	0.0197		—		—	—	—	—	—	11.33	3	"
"	76	"	"	—	0.0204		—		—	—	—	—	—	11.98	3	"
"	77	"	"	5.03	0.0208		101.59		4.21	9.26	42,601	0.0172	427.3	12.18	3	"
"	78	"	"	—	0.0211		—		—	—	—	—	—	11.93	3	"
"	79	"	"	—	0.0229		—		—	—	—	—	—	13.97	3	"
"	80	"	"	—	0.0257		—		—	—	—	—	—	14.51	3	"
"	81	15,433	20.12	17.65	0.0020		43.46		13.05	5.06	56,524	0.0265	566.9	0.14	410	Dunes
"	82	"	"	9.51	00054		80.68		6.52	5.88	52,471	0.0148	526.3	1.79	7	"
"	83	"	"	8.78	0.0051		87.39		5.55	5.27	48,330	0.0119	484.6	2.24	4	—
"	84	"	"	8.66	0.0056		88.64		5.61	5.55	49,560	0.0124	497.1	2.39	4	—
"	85	"	"	8.47	0.0057		90.53		5.43	5.51	48,966	0.0120	491.1	2.44	4	Transition
"	86	"	"	8.78	0.0058		87.39		5.82	5.75	50,727	0.0131	508.8	2.34	4	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE —27(cont.)

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Slope of bed, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds' Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
							Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
								SAND C (cont.)								
4C	87	15,433	20.12	9.24	0.0060		83.06		6.43	6.15	53,256	0.0150	534.2	2.04	7	—
"	88	"	"	9.39	0.0060		81.72		6.61	6.24	53,888	0.0155	541.5	2.34	8	Transition
"	89	"	"	9.14	0.0057		83.91		6.22	5.90	52,019	0.0141	521.8	2.63	8	"
"	90	"	"	7.77	0.0078		98.69		5.27	6.35	51,883	0.0126	520.4	3.78	4	"
"	91	"	"	7.92	0.0082		96.80		5.55	6.68	53,534	0.0136	537.0	4.37	3	"
"	92	"	"	6.80	0.0096		112.84		4.51	6.52	50,750	0.0110	509.0	5.82	3	"
"	93	"	"	6.80	0.0098		112.84		4.54	6.61	51,099	0.0112	512.5	5.72	3	"
"	94	"	"	6.95	0.0099		110.37		4.72	6.77	51,983	0.0112	521.4	6.01	3	"
"	95	"	"	7.38	0.0101		104.03		5.27	7.23	54,691	0.0136	548.6	6.46	3	Smooth
"	96	"	"	6.89	0.0112		111.34		4.85	7.30	53,794	0.0127	539.6	7.50	5	"
"	97	"	"	7.28	0.0112		105.34		5.30	7.63	55,705	0.0142	558.7	7.55	4	"
"	98	"	"	6.77	0.0121		113.39		4.85	7.58	54,785	0.0129	549.5	8.05	5	"
"	99	"	"	7.13	0.0153		107.59		5.55	9.12	59,501	0.0167	596.8	9.74	4	Antidunes
"	100	"	"	—	0.0156		—		—	—	—	—	—	11.88	4	"
"	101	"	"	—	0.0164		—		—	—	—	—	—	11.98	3	"
"	102	"	"	—	0.0169		—		—	—	—	—	—	12.52	3	"
"	103	"	"	—	0.0173		—		—	—	—	—	—	13.67	3	"
"	104	"	"	—	0.0204	No Observations	—	No Observations	—	—	—	—	—	17.20	3	"
"	105	20,785	20.12	9.97	0.0062		103.66		5.88	5.98	60,801	0.0115	609.8	3.03	4	Transition
"	106	"	"	9.69	0.0062		106.59		5.55	5.81	58,949	0.0108	591.3	3.18	4	"
"	107	"	"	9.75	0.0058		105.92		5.43	5.56	57,290	0.0103	574.6	3.33	4	"
"	108	"	"	8.02	0.0099		128.87		4.82	6.84	61,878	0.0102	620.6	8.35	3	"
"	109	"	"	8.44	0.0104		122.38		5.43	7.44	66,192	0.0119	663.9	8.10	3	"
"	110	5,154	30.48	3.57	0.0054		47.43		3.23	4.14	15,279	0.0157	153.3	0.25	9	Dunes
"	111	"	"	3.54	0.0057		47.82		3.23	4.25	15,405	0.0160	154.5	0.36	12	"
"	112	"	"	3.35	0.0073		50.44		3.08	4.69	15,479	0.0167	155.3	0.52	9	"
"	113	"	"	3.26	0.0075		51.85		2.99	4.69	15,442	0.0161	154.9	0.56	5	"
"	114	"	"	3.29	0.0074		51.3		3.02	4.68	15,454	0.0163	155.0	0.59	5	"
"	115	"	"	—	0.0091		—		—	—	—	—	—	0.85	10	"
"	116	"	"	—	0.0110		—		—	—	—	—	—	1.35	8	"
"	117	"	"	—	0.0131		—		—	—	—	—	—	1.77	6	Transition
"	118	"	"	—	0.0132		—		—	—	—	—	—	1.84	11	"
"	119	"	"	—	0.0152		—		—	—	—	—	—	2.30	3	Smooth
"	120	"	"	1.98	0.0168		85.34		1.80	5.44	15,298	0.0104	153.4	2.76	6	"
"	121	"	"	1.89	0.0185		89.46		1.71	5.57	15,225	0.0101	152.7	3.18	4	"
"	122	"	"	—	0.0196		—		—	—	—	—	—	3.48	4	Transition
"	123	"	"	1.55	0.0207		108.78		1.37	5.28	14,880	0.0076	149.3	3.74	4	Antidunes
"	124	"	"	1.98	0.0224		85.34		1.83	6.34	15,562	0.0122	156.1	4.20	4	"
"	125	"	"	—	0.0232		—		—	—	—	—	—	4.30	4	"
"	126	"	"	—	0.0248		—		—	—	—	—	—	4.76	3	"
"	127	"	"	—	0.0266		—		—	—	—	—	—	5.45	3	"
"	128	10,279	30.48	9.81	0.0019		34.35		8.57	4.00	29,333	0.0247	294.2	0.06	94	Dunes
"	129	"	"	8.11	0.0024		41.61		6.95	4.04	28,829	0.0199	289.2	0.17	41	"
"	130	"	"	6.37	0.0042		52.94		5.52	4.77	29,120	0.0178	292.1	0.59	10	"
"	131	"	"	5.70	0.0044		59.16		4.85	4.57	28,583	0.0149	286.7	0.79	8	"
"	132	"	"	5.00	0.0052		67.45		4.18	4.62	28,083	0.0129	281.7	0.98	6	"
"	133	"	"	5.12	0.0065		65.87		4.45	5.33	29,224	0.0154	293.1	1.28	7	—
"	134	"	"	4.33	0.0073		77.91		3.66	5.12	28,414	0.0121	285.0	1.51	6	Transition
"	135	"	"	4.36	0.0070		77.36		3.66	5.01	28,213	0.0119	283.0	1.57	4	"
"	136	"	"	4.30	0.0073		78.46		3.63	5.10	28,372	0.0120	284.6	1.57	4	"
"	137	"	"	4.39	0.0082		76.84		3.78	5.51	28,959	0.0133	290.5	1.90	6	"
"	138	"	"	4.05	0.0083		83.18		3.41	5.27	28,313	0.0115	284.0	2.00	5	"
"	139	"	"	4.11	0.0095		81.96		3.54	5.74	28,894	0.0128	289.8	2.72	8	Smooth
"	140	"	"	—	0.0097		—		—	—	—	—	—	2.66	3	"
"	141	"	"	3.75	0.0093		89.95		3.14	5.35	28,151	0.0107	282.4	2.82	9	"
"	142	"	"	—	0.0096		—		—	—	—	—	—	2.76	3	"
"	143	"	"	4.05	0.0097		83.18		3.48	5.75	28,819	0.0126	289.1	2.82	5	"
"	144	"	"	3.69	0.0109		91.44		3.14	5.79	28,617	0.0114	287.0	3.41	5	"
"	145	"	"	4.05	0.0109		83.18		3.54	6.15	29,324	0.0136	294.1	3.41	5	"
"	146	"	"	3.47	0.0125		97.05		2.96	6.02	28.612	0.0110	287.0	4.07	3	"
"	147	"	"	3.47	0.0126		97.05		2.96	6.04	28,612	0.0111	287.0	4.30	3	"
"	148	"	"	3.51	0.0138		96.23		3.05	6.42	29,243	0.0119	293.3	4.82	5	"
"	149	"	"	—	0.0150		—		—	—	—	—	—	5.45	5	Antidunes

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, ond V_m is in feet per eecond.

(2) Dry weight.

TABLE — 27(cont.)

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Slope of bed, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds' Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
							Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND C (cont.)																
4C	150	10,279	30.48	—	0.0199	No Observations	—	No Observations	—	—	—	—	—	7.64	4	Antidunes
"	151	"	"	—	0.0198		—		—	—	—	—	—	8.43	3	"
"	152	"	"	—	0.0210		—		—	—	—	—	—	8.40	3	"
"	153	"	"	—	0.0211		—		—	—	—	—	—	8.37	4	"
"	154	"	"	—	0.0248		—		—	—	—	—	—	11.45	3	"
"	155	"	"	—	0.0265		—		—	—	—	—	—	11.88	3	"
"	156	15,433	30.48	6.43	0.0051		78.73		5.09	5.05	39,950	0.0125	400.7	1.57	.5	Dunes
"	157	"	"	6.28	0.0053		80.65		4.97	5.09	39,960	0.0122	400.8	1.87	5	"
"	158	"	"	5.88	0.0061		86.08		4.66	5.28	39,990	0.0118	401.1	2.23	4	Transition
"	159	"	"	5.76	0.0062		87.90		4.54	5.25	39,790	0.0114	399.1	2.10	4	"
"	160	"	"	5.88	0.0062		86.08		4.66	5.32	39,990	0.0118	401.1	2.33	5	"
"	161	"	"	5.36	0.0083		94.40		4.36	5.96	41,037	0.0120	411.6	3.51	5	—
"	162	"	"	5.33	0.0088		94.91		4.36	6.14	41,256	0.0122	413.8	3.51	5	Smooth
"	163	"	"	5.09	0.0102		99.46		4.21	6.49	41,744	0.0123	418.7	4.92	3	"
"	164	"	"	5.27	0.0105		96.01		4.42	6.75	42,313	0.0134	424.4	5.02	4	"
"	165	"	"	4.97	0.0109		101.93		4.11	6.63	41,764	0.0122	418.9	5.41	4	"
"	166	"	"	4.88	0.0100		103.81		3.96	6.19	40,987	0.0112	411.1	5.54	5	"
"	167	"	"	5.06	0.0112		100.07		4.24	6.83	42,303	0.0128	424.3	5.68	3	"
"	168	"	"	4.88	0.0112		103.81		4.02	6.65	41,605	0.0120	417.3	5.94	3	"
"	169	"	"	4.51	0.0128		112.23		3.72	6.83	41,625	0.0112	417.5	6.73	4	"
"	170	"	"	4.15	0.0150		122.13		3.41	7.08	41,525	0.0106	416.5	8.73	4	Transition
"	171	"	"	—	0.0160		—		—	—	—	—	—	10.33	3	Antidunes
"	172	"	"	—	0.0170		—		—	—	—	—	—	9.58	4	"
"	173	"	"	—	0.0175		—		—	—	—	—	—	9.71	4	"
"	174	"	"	—	0.0187		—		—	—	—	—	—	9.22	3	"
"	175	"	"	—	0.0195		—		—	—	—	—	—	11.65	3	"
"	176	"	"	—	0.0194		—		—	—	—	—	—	12.83	3	"
"	177	"	"	—	0.0197		—		—	—	—	—	—	13.06	3	"
"	178	"	"	—	0.0217		—		—	—	—	—	—	14.14	3	"
"	179	20,785	30.48	17.71	0.0013		38.50		14.20	4.26	54,521	0.0255	546.9	0.05	60	Dunes
"	180	"	"	—	0.0016		—		—	—	—	—	—	0.07	170	"
"	181	"	"	—	0.0014		—		—	—	—	—	—	0.10	180	"
"	182	"	"	—	0.0021		—		—	—	—	—	—	0.43	12	"
"	183	"	"	13.99	0.0027		48.74		11.70	5.57	56,874	0.0255	570.5	0.49	20	"
"	184	"	"	12.80	0.0033		53.28		10.76	5.90	57,153	0.0244	573.2	0.46	12	"
"	185	"	"	9.81	0.0034		69.49		7.53	5.01	52,163	0.0149	523.2	1.28	8	"
"	186	"	"	7.07	0.0058		96.44		5.27	5.48	50,701	0.0111	508.5	2.76	4	Transition
"	187	"	"	7.35	0.0058		92.84		5.58	5.63	51,631	0.0120	517.9	2.79	4	"
"	188	"	"	7.96	0.0057		85.71		6.22	5.90	53,135	0.0139	532.9	3.84	5	"
"	189	"	"	7.59	0.0061		89.86		5.91	5.95	52,975	0.0132	531.3	2.53	4	"
"	190	"	"	7.10	0.0059		96.01		5.33	5.56	51,059	0.0114	512.1	3.12	6	"
"	191	"	"	6.74	0.0081		101.22		5.30	6.49	53,526	0.0125	536.9	4.33	4	"
"	192	"	"	5.91	0.0099		115.34		4.60	6.68	52,920	0.0111	530.8	6.36	3	—
"	193	"	"	6.19	0.0101		110.22		4.91	6.97	53,923	0.0122	540.9	5.94	6	Smooth
"	194	"	"	5.70	0.0115		119.63		4.48	7.11	53,446	0.0113	536.1	7.55	4	"
"	195	"	"	6.07	0.0129		112.41		5.00	7.95	56,026	0.0137	561.9	8.76	4	Transition
"	196	"	"	—	0.0143		—		—	—	—	—	—	10.10	4	Antidunes
"	197	"	"	—	0.0150		—		—	—	—	—	—	10.14	3	"
"	198	"	"	—	0.0151		—		—	—	—	—	—	10.79	3	"
"	199	"	"	—	0.0178		—		—	—	—	—	—	14.57	3	"
"	200	"	"	—	0.0207		—		—	—	—	—	—	16.44	3	"
"	201	"	"	9.51	0.0057		71.72		7.93	6.66	56,668	0.0194	568.4	3.87	3	Transition
"	202	"	"	9.30	0.0066		73.37		7.86	7.13	57,525	0.0203	577.0	4.23	3	"
"	203	"	"	7.80	0.0117		87.39		6.77	8.81	58,960	0.0206	591.4	11.42	2	Smooth
"	204	"	"	7.71	0.0122		88.42		6.71	8.96	59,117	0.0206	592.9	12.14	2	"
"	205	5,154	40.23	2.83	0.0066		45.17		2.68	4.17	12,079	0.0161	121.2	0.24	10	Dunes
"	206	"	"	3.05	0.0070		42.03		2.90	4.46	12,136	0.0188	121.7	0.19	9	"
"	207	"	"	2.74	0.0084		46.70		2.62	4.65	12,203	0.0173	122.4	0.32	6	"
"	208	"	"	2.32	0.0098		55.32		2.20	4.59	12,107	0.0140	121.4	0.52	5	"
"	209	"	"	2.04	0.0114		62.73		1.92	4.63	12,008	0.0122	120.4	0.75	6	Transition
"	210	"	"	2.04	0.0124		62.73		1.92	4.83	12,008	0.0127	120.4	1.07	5	"
"	211	"	"	1.68	0.0164		76.41		1.59	5.05	12,075	0.0106	121.1	1.44	5	Smooth
"	212	"	"	1.22	0.0208		105.06		1.13	4.80	11,816	0.0069	118.5	2.46	5	Transition

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE—27(cont.)

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Slope of bed, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds' Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
							Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND C (cont.)																
4C	213	5,154	40.23	1.49	0.0223		85.77		1.40	5.54	11,989	0.0101	120.3	2.98	5	Antidunes
"	214	"	"	1.71	0.0210		75.04		1.62	5.77	12,083	0.0123	121.2	3.13	4	"
"	215	"	"	1.55	0.0229		82.42		1.46	5.73	12,022	0.0110	120.6	3.23	4	"
"	216	"	"	1.37	0.0234		93.39		1.28	5.42	11,918	0.0090	119.5	3.50	3	"
"	217	10,279	40.23	4.97	0.0032		51.42		4.39	3.71	22,500	0.0137	225.7	0.22	6	Dunes
"	218	"	"	5.21	0.0035		49.01		4.66	4.00	22,785	0.0157	228.5	0.25	6	"
"	219	"	"	4.27	0.0056		59.86		3.84	4.59	22,917	0.0142	229.9	0.65	6	"
"	220	"	"	3.87	0.0056		66.02		3.44	4.35	22,669	0.0120	227.4	0.67	6	"
"	221	"	"	3.75	0.0072		68.12		3.38	4.89	22,976	0.0131	230.5	0.94	5	"
"	222	"	"	3.72	0.0079		68.73		3.38	5.12	23,181	0.0136	232.5	1.27	5	"
"	223	"	"	3.66	0.0089		69.86		3.35	5.41	23,354	0.0140	234.2	1.49	5	Transition
"	224	"	"	3.23	0.0107		79.10		2.93	5.54	23,076	0.0124	231.5	2.11	5	Smooth
"	225	"	"	3.17	0.0123		80.56		2.90	5.91	23,260	0.0130	233.3	2.76	6	"
"	226	"	"	3.05	0.0127		83.82		2.77	5.88	23,182	0.0123	232.5	2.93	5	"
"	227	"	"	2.96	0.0132		86.44		2.68	5.89	23,114	0.0119	231.8	3.23	4	"
"	228	"	"	2.59	0.0133		98.60		2.32	5.50	22,768	0.0095	228.4	3.21	4	"
"	229	"	"	2.74	0.0146		93.15		2.50	5.98	23,208	0.0111	232.8	3.83	4	Transition
"	230	"	"	2.71	0.0144		94.15		2.47	5.91	23,176	0.0108	232.5	3.93	4	"
"	231	"	"	—	0.0180	No Observations	—	No Observations	—	—	—	—	—	4.72	3	Antidunes
"	232	"	"	—	0.0192		—		—	—	—	—	—	5.89	3	"
"	233	"	"	—	0.0214		—		—	—	—	—	—	6.56	3	"
"	234	"	"	—	0.0218		—		—	—	—	—	—	6.61	3	"
"	235	"	"	—	0.0230		—		—	—	—	—	—	7.46	3	"
"	236	"	"	—	0.0246		—		—	—	—	—	—	7.66	3	"
"	237	15,433	40.23	5.67	0.0056		67.67		5.00	5.24	33,727	0.0150	338.3	0.89	6	Dunes
"	238	"	"	5.24	0.0062		73.18		4.60	5.29	33,576	0.0139	336.8	1.37	6	"
"	239	"	"	4.63	0.0069		82.81		3.99	5.20	32,967	0.0117	330.7	1.96	5	"
"	240	"	"	4.63	0.0083		82.81		4.08	5.77	33,719	0.0131	338.2	2.39	5	Transition
"	241	"	"	4.30	0.0085		89.28		3.75	5.59	33,371	0.0116	334.7	2.93	5	Smooth
"	242	"	"	4.02	0.0110		95.37		3.54	6.18	33,622	0.0119	337.2	3.95	5	"
"	243	"	"	3.60	0.0137		106.62		3.17	6.53	33,698	0.0110	338.0	5.22	5	Transition
"	244	"	"	—	0.0157		—		—	—	—	—	—	6.16	4	Antidunes
"	245	"	"	—	0.0158		—		—	—	—	—	—	6.36	3	"
"	246	"	"	—	0.0189		—		—	—	—	—	—	8.45	3	"
"	247	"	"	-	0.0195		—		—	—	—	—	—	9.00	3	"
"	248	"	"	—	0.0208		—		—	—	—	—	—	10.12	3	"
"	249	"	"	—	0.0220		—		—	—	—	—	—	9.79	3	"
"	250	20,785	40.23	12.47	0.0016		41.45		10.67	4.09	44,081	0.0211	442.2	0.12	120	Dunes
"	251	"	"	9.88	0.0020		52.30		8.17	4.00	42,596	0.0161	427.2	0.35	—	"
"	252	"	"	8.90	0.0035		58.06		7.71	5.14	44,636	0.0185	447.7	0.72	—	"
"	253	"	"	6.40	0.0051		80.71		5.36	5.18	43,164	0.0126	432.9	1.32	—	"
"	254	"	"	6.52	0.0050		79.19		5.49	5.19	43,314	0.0129	434.4	1.44	6	"
"	255	"	"	5.76	0.0055		89.67		4.72	5.05	42,233	0.0108	423.6	1.84	—	—
"	256	"	"	5.67	0.0065		91.14		4.72	5.49	42,926	0.0116	430.6	2.61	5	Transition
"	257	"	"	3.57	0.0075		144.90		2.53	4.31	36,530	0.0032	366.6	2.81	—	—
"	258	"	"	5.58	0.0073		92.60		4.72	5.82	43,613	0.0121	437.4	2.98	—	—
"	259	"	"	5.09	0.0087		101.50		4.30	6.06	43,495	0.0113	436.3	3.95	4	Smooth
"	260	"	"	4.97	0.0105		103.97		4.30	6.65	44,542	0.0121	446.8	5.64	4	"
"	261	"	"	4.54	0.0115		113.75		3.87	6.61	43,901	0.0107	440.3	6.26	4	"
"	262	"	"	4.36	0.0137		118.51		3.75	7.10	44,296	0.0111	444.3	7.68	3	Transition
"	263	"	"	—	0.0162		—		—	—	—	—	—	9.15	3	Antidunes
"	264	"	"	—	0.0172		—		--	—	—	—	—	10.07	3	"
"	265	"	"	—	0.0182		—		—	—	—	—	—	10.74	3	"
"	266	"	"	—	0.0190		—		—	—	—	—	—	11.33	3	"
"	267	10,279	39.74	3.90	0.0035		44.10		3.66	3.54	16,084	0.0148	161.3	0.16	10	Dunes
"	268	"	"	3.23	0.0059		53.25		3.05	4.20	16,182	0.0141	162.3	0.27	6	"
"	269	"	"	3.20	0.0071		53.77		3.05	4.61	16,340	0.0153	163.9	0.44	10	"
"	270	"	"	3.05	0.0090		56.45		2.93	5.08	16,468	0.0160	165.2	0.67	7	Transition
"	271	"	"	2.71	0.0099		63.43		2.59	5.02	16,386	0.0138	164.4	1.00	4	"
"	272	"	"	2.44	0.0109		70.56		2.32	4.98	16,293	0.0120	163.4	1.29	4	"
"	273	"	"	2.38	0.0121		72.36		2.26	5.17	16,275	0.0121	163.2	1.51	4	Smooth
"	274	"	"	2.04	0.0141		84.28		1.92	5.15	16,134	0.0101	161.8	2.08	4	"
"	275	"	"	1.92	0.0163		89.58		1.83	5.41	16,335	0.0099	163.4	2.73	4	Transition

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE—27(cont.)

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Slope of bed, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds' Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, $G^{(2)}$ grams per second per centimeter	Duration of run minutes	Bed condition
							Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11).	(12)	(13)	(14)	(15)	(16)	(17)
SAND C (cont.)																
4C	276	10,279	59.74	1.95	0.0167		88.24		1.86	5.52	16,355	0.0103	164.0	2.93	4	Transition
"	277	"	"	2.04	0.0185		84.28		1.95	5.95	16,394	0.0117	164.4	3.40	4	"
"	278	"	"	1.86	0.0193		92.51		1.77	5.78	16,307	0.0102	163.6	3.80	4	"
"	279	"	"	1.83	0.0203		94.09		1.74	5.88	16,294	0.0102	163.4	3.80	4	"
"	280	15,433	59.74	4.51	0.0056		57.27		4.24	4.82	24,192	0.0159	242.7	0.50	8	Dunes
"	281	"	"	3.87	0.0070		66.75		3.63	4.99	24,138	0.0137	242.1	0.92	5	"
"	282	"	"	3.44	0.0079		74.98		3.20	4.98	23,922	0.0120	239.9	1.32	5	"
"	283	"	"	3.51	0.0092		73.70		3.29	5.45	24,189	0.0134	242.6	1.69	6	Transition
"	284	"	"	3.05	0.0107		84.76		2.84	5.45	23,957	0.0113	240.3	2.31	5	Smooth
"	285	"	"	2.99	0.0110		86.47		2.77	5.47	23,915	0.0111	239.9	2.76	4	"
"	286	"	"	2.87	0.0134		90.19		2.68	5.94	24,117	0.0115	241.9	3.52	4	Transition
"	287	"	"	2.87	0.0138		90.19		2.68	6.02	24,117	0.0117	241.9	4.03	4	"
"	288	"	"	2.44	0.0158		105.95		2.26	5.91	23,831	0.0095	239.0	4.45	4	"
"	289	"	"	2.16	0.0185		119.33		2.01	6.04	23,937	0.0084	240.1	5.37	3	Antidunes
"	290	"	"	—	0.0185		—		—	—	—	—	—	5.54	3	"
"	291	"	"	—	0.0196		—		—	—	—	—	—	5.94	3	"
"	292	"	"	—	0.0206		—		—	—	—	—	—	6.46	3	"
"	293	20,785	59.74	6.25	0.0045	No Observations	55.69	No Observations	5.82	5.07	32,326	0.0181	324.2	0.54	8	Dunes
"	294	"	"	5.91	0.0041		58.86		5.43	4.67	31,836	0.0156	319.3	0.69	10	"
"	295	"	"	5.39	0.0037		64.50		4.85	4.19	31,764	0.0125	312.6	0.82	5	"
"	296	"	"	5.21	0.0049		66.75		4.76	4.78	31,645	0.0138	317.4	0.92	5	"
"	297	"	"	4.54	0.0060		76.63		4.15	4.94	31,668	0.0121	317.6	1.05	6	"
"	298	"	"	5.03	0.0058		69.19		4.63	5.13	31,960	0.0142	320.6	1.22	7	"
"	299	"	"	4.72	0.0061		73.64		4.33	5.09	31,776	0.0131	318.7	1.21	5	"
"	300	"	"	4.72	0.0060		73.64		4.33	5.05	31,776	0.0130	318.7	1.46	4	Transition
"	301	"	"	3.66	0.0070		95.13		3.26	4.73	30,929	0.0090	310.2	1.69	6	"
"	302	"	"	4.48	0.0075		77.66		4.15	5.52	32,094	0.0134	321.9	1.61	5	Dunes
"	303	"	"	4.24	0.0092		82.14		3.93	5.96	32,200	0.0135	323.0	2.78	3	Transition
"	304	"	"	3.57	0.0117		97.57		3.29	6.15	32,024	0.0114	321.2	4.03	4	Smooth
"	305	"	"	3.44	0.0122		101.01		3.17	6.16	31,924	0.0110	320.2	4.34	4	"
"	306	"	"	3.23	0.0131		107.66		2.96	6.16	31,740	0.0102	318.4	5.06	3	Transition
"	307	"	"	3.20	0.0153		108.72		2.96	6.66	32,053	0.0109	321.5	5.59	3	Antidunes
"	308	"	"	—	0.0149		—		—	—	—	—	—	5.86	3	"
"	309	"	"	—	0.0145		—		—	—	—	—	—	6.06	3	"
"	310	"	"	—	0.0150		—		—	—	—	—	—	6.16	3	"
"	311	31,687	59.74	6.77	0.0053		78.39		6.07	5.62	47,409	0.0144	475.5	1.51	5	Dunes
"	312	"	"	5.73	0.0061		92.57		5.06	5.50	46,700	0.0116	468.4	1.87	6	—
"	313	"	"	5.61	0.0064		94.58		4.94	5.57	46,564	0.0114	467.0	2.19	4	Smooth
"	314	"	"	5.49	0.0056		96.68		4.76	5.11	45,833	0.0102	459.7	2.31	6	"
"	315	"	"	5.97	0.0065		88.79		5.33	5.83	47,219	0.0129	473.6	2.34	5	—
"	316	"	"	5.67	0.0069		93.54		5.06	5.85	47,189	0.0122	473.3	2.49	5	Smooth
"	317	"	"	5.76	0.0071		92.08		5.15	5.99	47,288	0.0127	474.3	2.64	4	"
"	318	"	"	5.43	0.0078		97.75		4.85	6.09	47,228	0.0120	473.7	3.60	5	"
"	319	"	"	5.21	0.0078		101.74		4.63	5.95	46,995	0.0112	471.4	4.24	3	"
"	320	"	"	5.06	0.0097		104.82		4.54	6.57	47,467	0.0120	476.1	5.54	3	"
"	321	"	"	4.63	0.0103		114.48		4.12	6.45	46,968	0.0106	471.1	6.03	3	"
"	322	"	"	—	0.0112		—		—	—	—	—	—	6.65	3	Transition
SAND D																
4D	1	2,633	20.12	2.35	0.0080		55.78		2.04	4.00	11,356	0.0120	113.9	0.26	6	Dunes
"	2	"	"	2.35	0.0094		55.78		2.07	4.37	11,528	0.0131	115.6	0.40	6	"
"	3	"	"	2.29	0.0119		57.27		2.04	4.88	11,660	0.0142	117.0	0.65	5	Transition
"	4	"	"	2.32	0.0139		56.51		2.10	5.35	11,848	0.0159	118.8	0.99	4	"
"	5	"	"	1.92	0.0168		68.18		1.71	5.30	11,603	0.0126	116.4	1.04	5	Smooth
"	6	"	"	1.77	0.0183		74.04		1.59	5.33	11,700	0.0115	117.4	1.44	4	"
"	7	"	"	1.86	0.0188		70.41		1.68	5.56	11,766	0.0128	118.0	1.79	6	"
"	8	"	"	1.92	0.0198		68.18		1.74	5.81	11,808	0.0138	118.4	2.24	4	"
"	9	"	"	1.71	0.0225		76.69		1.52	5.80	11,653	0.0120	116.9	2.34	4	"
"	10	"	"	1.71	0.0247		76.69		1.55	6.14	11,882	0.0128	119.2	3.08	4	"
"	11	5,154	20.12	5.06	0.0039		50.63		4.05	3.94	20,464	0.0146	205.3	0.29	7	Dunes
"	12	"	"	4.48	0.0077		57.18		3.84	5.39	21,891	0.0175	219.6	0.70	6	"
"	13	"	"	4.11	0.0082		62.27		3.48	5.29	21,574	0.0155	216.4	0.84	6	"
"	14	"	"	3.75	0.0095		68.34		3.14	5.41	21,388	0.0142	214.5	1.14	6	Transition
"	15	"	"	3.20	0.0110		80.04		2.62	5.32	20,915	0.0116	209.8	1.49	5	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE — 27 (cont.)

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Slope of bed, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds' Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, $G^{(2)}$ grams per second per centimeter	Duration of run minutes	Bed condition
							Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND D (cont.)																
4D	16	5,154	20.12	3.29	00126		77.82		2.77	5.85	21,522	0.0132	215.9	2.34	4	Smooth
"	17	"	"	3.29	00140		77.82		2.80	6.20	21,756	0.0140	218.2	2.63	4	"
"	18	"	"	2.74	00195		93.39		2.35	6.70	21,853	0.0123	219.2	4.13	8	"
"	19	"	"	2.74	00210		93.39		2.35	6.95	21,853	0.0127	219.2	5.37	9	"
"	20	"	"	2.74	00226		93.39		2.38	7.26	22,133	0.0133	222.0	6.01	4	"
"	21	"	"	2.83	00228		90.37		2.47	7.43	22,245	0.0142	223.1	6.31	4	"
"	22	"	"	2.74	00239		93.39		2.38	7.46	22,133	0.0137	222.0	6.66	4	"
"	23	15,433	20.12	14.02	0.0019		54.7		8.66	4.02	47,215	0.0156	473.6	0.34	6	Dunes
"	24	"	"	12.86	0.0020		59.65		7.50	3.84	44,592	0.0133	447.3	0.47	5	"
"	25	"	"	12.28	0.0051		62.45		9.57	6.92	59,592	0.0240	597.7	0.84	5	"
"	26	"	"	9.69	00057		79.13		6.86	6.19	54,105	0.0160	542.7	1.34	5	—
"	27	"	"	9.63	0.0064		79.64		7.01	6.63	55,661	0.0171	558.3	1.84	4	—
"	28	"	"	8.14	0.0081		94.27		5.76	6.77	54,147	0.0142	543.1	3.18	5	Transition
"	29	"	"	7.22	0.0096		106.22		5.00	6.86	52,940	0.0125	531.0	4.57	4	Smooth
"	30	"	"	6.61	00125		116.01		4.72	7.61	54,639	0.0126	548.0	7.21	4	"
"	31	"	"	6.43	0.0142		119.24		4.66	8.06	55,436	0.0130	556.0	8.55	4	"
"	32	"	"	6.16	00155		124.63		4.48	8.25	55,680	0.0126	558.5	10.09	4	"
"	33	"	"	6.37	00158	No Observations	120.46	No Observations	4.76	8.58	57,108	0.0137	572.8	10.39	4	"
"	34	"	"	5.82	0.0157		131.73		4.12	7.96	54,045	0.0113	542.1	10.83	3	"
"	35	"	"	5.39	00165		142.22		3.69	7.73	52,294	0.0100	524.5	11.48	3	"
"	36	"	"	5.97	0.0198		128.38		4.57	9.42	58,519	0.0141	587.0	16.45	3	"
"	37	"	"	—	0.0202		—		—	—	—	—	—	15.42	3	Transition
"	38	5,154	30.48	3.35	0.0069		50.44		3.08	4.56	15,479	0.0162	155.3	0.31	7	Dunes
"	39	"	"	3.05	0.0084		55.47		2.80	4.81	15,507	0.0153	155.5	0.52	5	"
"	40	"	"	2.87	0.0106		59.01		2.65	5.25	15,602	0.0155	156.5	0.72	5	Transition
"	41	"	"	3.02	0.0108		56.02		2.80	5.45	15,661	0.0171	157.1	0.89	5	"
"	42	"	"	2.68	0.0114		63.03		2.47	5.25	15,515	0.0144	155.6	0.92	4	"
"	43	"	"	2.62	0.0134		64.50		2.44	5.66	15,678	0.0151	157.3	1.57	4	"
"	44	"	"	2.50	0.0139		67.67		2.32	5.62	15,625	0.0142	156.7	1.61	4	Smooth
"	45	"	"	2.16	0.0157		78.12		1.98	5.52	15,430	0.0117	154.8	1.84	4	"
"	46	"	"	2.01	0.0183		84.06		1.83	5.73	15,329	0.0112	153.8	2.62	4	"
"	47	"	"	2.13	0.0209		79.25		1.98	6.37	15,652	0.0134	157.0	3.22	4	"
"	48	"	"	2.01	0.0233		84.06		1.86	6.52	15,580	0.0128	156.3	3.58	4	"
"	49	"	"	1.89	0.0255		89.46		1.74	6.59	15,493	0.0120	155.4	4.13	4	"
"	50	"	"	1.95	0.0275		86.69		1.83	7.02	15,809	0.0133	158.6	4.99	3	"
"	51	10,279	"	12.74	—		26.46		—	—	—	—	—	0.0	—	Dunes
"	52	"	"	8.90	0.0018		37.89		7.56	3.65	28,555	0.0201	286.4	0.08	81	"
"	53	"	"	8.63	0.0018		39.11		7.25	3.58	28,285	0.0189	283.7	0.07	66	"
"	54	"	"	7.47	0.0025		45.17		6.31	3.93	28,413	0.0176	285.0	0.18	20	"
"	55	"	"	6.83	0.0035		49.41		5.88	4.49	28,981	0.0181	290.7	0.39	22	"
"	56	"	"	7.16	0.0043		47.09		6.37	5.18	29,906	0.0222	300.0	0.39	26	"
"	57	"	"	6.37	0.0058		52.94		5.70	5.69	30,086	0.0213	301.8	0.75	12	"
"	58	"	"	5.18	0.0065		65.07		4.51	5.36	29,265	0.0157	293.5	0.92	6	"
"	59	"	"	5.00	0.0080		67.45		4.42	5.89	29,724	0.0166	298.1	1.15	5	Transition
"	60	"	"	4.15	0.0114		81.35		3.66	6.40	29,669	0.0145	297.6	2.82	4	Smooth
"	61	"	"	3.66	0.0132		92.20		3.20	6.44	29,416	0.0126	295.0	3.67	4	"
"	62	"	"	3.54	0.0144		95.37		3.08	6.59	29,267	0.0124	293.6	4.27	4	"
"	63	"	"	3.57	0.0149		94.58		3.14	6.77	29,600	0.0128	296.9	4.63	3	"
"	64	"	"	3.51	0.0165		96.23		3.11	7.09	29,829	0.0132	299.2	5.58	3	"
"	65	"	"	3.14	0.0175		107.41		2.74	6.86	29,375	0.0112	294.6	5.94	4	"
"	66	"	"	3.17	0.0194		106.38		2.80	7.30	29,740	0.0121	298.3	7.51	4	"
"	67	"	"	3.08	0.0211		109.55		2.71	7.49	29,632	0.0120	297.2	8.46	3	"
"	68	15,433	"	7.19	0.0053		70.38		5.97	5.57	41,919	0.0158	420.5	0.98	4	—
"	69	"	"	7.35	0.0055		68.92		6.16	5.76	42,307	0.0168	424.3	1.02	4	—
"	70	"	"	5.70	0.0078		88.82		4.66	5.97	41,293	0.0129	414.2	2.17	4	Transition
"	71	"	"	5.06	0.0111		100.07		4.21	6.77	41,963	0.0127	420.9	4.69	4	Smooth
"	72	"	"	4.94	0.0126		102.53		4.18	7.18	42,689	0.0131	428.2	5.51	4	"
"	73	"	"	4.15	0.0158		122.13		3.44	7.31	41,936	0.0109	420.6	7.51	4	"
"	74	"	"	4.15	0.0161		122.13		3.44	7.37	41,936	0.0110	420.6	8.40	3	"
"	75	"	"	4.27	0.0162		118.66		3.57	7.53	42,187	0.0116	423.1	9.22	3	"
"	76	"	"	4.15	0.0174		122.13		3.48	7.70	42,313	0.0115	424.4	10.17	3	"
"	77	"	"	4.15	0.0191		122.13		3.54	8.14	43,056	0.0122	431.9	11.15	3	"
"	78	20,785	"	—	—		—		—	—	—	—	—	0.0	—	Dunes forming

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE—27(cont.)

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Slope of bed, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds' Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, $G^{(2)}$ grams per second per centimeter	Duration of run minutes	Bed condition
							Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
							SAND D (cont.)									
4D	79	20,785	30.48	14.97	0.0021	No Observations	45.57	No Observations	12.31	5.04	55,947	0.0249	561.2	0.21	29	Dunes
"	80	"	"	12.89	0.0032		52.88		10.79	5.82	56,887	0.0242	570.6	0.39	18	"
"	81	"	"	12.59	0.0037		54.16		10.70	6.23	57,767	0.0253	579.4	0.69	15	"
"	82	"	"	8.69	0.0061		78.49		7.10	6.52	55,577	0.0171	557.4	1.84	4	"
"	83	"	"	7.62	0.0061		89.49		5.94	5.96	53,034	0.0133	531.9	2.17	4	"
"	84	"	"	7.35	0.0075		92.84		5.88	6.58	54,455	0.0141	546.2	2.69	3	Smooth
"	85	"	"	6.71	0.0083		101.68		5.27	6.55	53,456	0.0126	536.2	3.54	4	Transition
"	86	"	"	6.28	0.0098		108.60		5.00	6.93	54,127	0.0124	542.9	5.58	3	Smooth
"	87	"	"	6.04	0.0109		112.99		4.82	7.18	54,253	0.0122	544.2	6.20	4	"
"	88	"	"	5.94	0.0119		114.73		4.79	7.47	54,734	0.0126	549.0	6.33	4	"
"	89	"	"	5.76	0.0139		118.38		4.72	8.02	55,756	0.0130	559.2	8.69	3	"
"	90	"	"	5.64	0.0146		120.94		4.63	8.14	55,864	0.0129	560.3	9.61	3	"
"	91	"	"	5.33	0.0173		127.83		4.42	8.66	56,332	0.0129	565.0	11.61	3	"
"	92	"	"	4.94	0.0176		138.10		3.99	8.30	54,978	0.0112	551.4	12.37	3	"
"	93	10,279	40.23	4.18	0.0030		61.20		3.51	3.21	21,387	0.0096	214.5	0.27	10	Dunes
"	94	"	"	5.21	0.0034		49.01		4.66	3.94	22,785	0.0154	228.5	0.27	10	"
"	95	"	"	4.18	0.0067		61.20		3.81	5.00	23,247	0.0152	233.2	0.57	8	"
"	96	"	"	3.78	0.0100		67.57		3.51	5.86	23,612	0.0158	236.8	1.32	5	"
"	97	"	"	3.93	0.0105		64.98		3.66	6.14	23,699	0.0174	237.7	1.42	2	"
"	98	"	"	3.26	0.0125		78.36		2.99	6.05	23,336	0.0138	234.1	2.21	4	—
"	99	"	"	3.38	0.0125		75.53		3.14	6.20	23,638	0.0148	237.1	2.41	3	Smooth
"	100	"	"	2.74	0.0154		93.15		2.50	6.14	23,208	0.0114	232.8	3.36	3	"
"	101	"	"	2.87	0.0157		89.15		2.62	6.35	23,296	0.0124	233.7	3.38	3	"
"	102	"	"	2.71	0.0167		94.15		2.47	6.36	23,176	0.0116	232.5	4.00	3	"
"	103	"	"	2.68	0.0189		95.22		2.47	6.77	23,440	0.0122	235.1	5.87	3	"
"	104	"	"	2.65	0.0191		96.38		2.44	6.76	23,427	0.0121	235.0	6.14	3	"
"	105	20.785	"	10.97	0.0034		47.09		9.88	5.74	46,367	0.0265	465.1	0.37	10	Dunes
"	106	"	"	8.29	0.0037		62.33		7.13	5.09	44,321	0.0168	444.5	0.62	10	"
"	107	"	"	7.41	0.0052		69.74		6.43	5.73	44,716	0.0166	448.5	1.07	10	"
"	108	"	"	6.83	0.0058		75.65		5.91	5.80	44.598	0.0153	447.3	1.22	8	"
"	109	"	"	7.10	0.0061		72.73		6.25	6.11	45,306	0.0170	454.4	1.17	8	"
"	110	"	"	6.16	0.0062		83.91		5.24	5.65	43,862	0.0131	439.9	1.49	5	—
"	111	"	"	6.13	0.0055		84.34		5.12	5.26	43,062	0.0122	431.9	1.79	5	—
"	112	"	"	6.28	0.0070		82.30		5.46	6.12	44.769	0.0147	449.0	1.47	5	—
"	113	"	"	5.61	0.0079		92.11		4.82	6.11	44,227	0.0128	443.6	1.79	5	—
"	114	"	"	5.52	0.0067		93.63		4.60	5.50	42,960	0.0112	430.9	2.06	5	—
"	115	"	"	—	0.0115		—		—	—	—	—	—	2.09	4	Smooth
"	116	"	"	4.69	0.0100		110.03		3.96	6.23	43,464	0.0106	435.9	4.23	3	"
"	117	"	"	4.88	0.0098		105.92		4.15	6.31	43,773	0.0112	439.0	4.33	3	"
"	118	"	"	4.75	0.0115		108.66		4.08	6.79	44,244	0.0117	443.8	5.20	3	"
"	119	"	"	4.63	0.0117		111.53		3.96	6.74	44,056	0.0113	441.9	4.97	3	"
							SAND E									
4E	1	5.154	20.12	3.81	0.0120		67.24		3.32	6.25	22,270	0.0168	223.4	1.04	15	Dunes
"	2	"	"	3.57	0.0127		71.84		3.08	6.19	22,046	0.0154	221.1	1.04	19	—
"	3	"	"	3.51	0.0143		73.09		3.05	6.54	22,211	0.0160	222.8	1.39	15	Transition
"	4	"	"	3.51	0.0148		73.09		3.05	6.65	22,211	0.0162	222.8	1.54	13	—
"	5	"	"	3.47	0.0156		73.73		3.05	6.83	22,406	0.0165	224.7	1.49	15	—
"	6	10,279	"	6.10	0.0104		83.82		4.85	7.03	40,498	0.0162	406.2	1.54	9	Transition
"	7	"	"	—	0.0104		—		—	—	—	—	—	1.54	9	—
"	8	"	"	6.00	0.0127		85.10		4.94	7.84	41,896	0.0178	420.2	2.09	9	Transition
"	9	"	"	6.10	0.0126		83.82		5.03	7.88	42,027	0.0183	421.5	2.29	10	—
"	10	"	"	5.64	0.0129		90.62		4.54	7.58	41,037	0.0160	411.6	2.34	10	—
"	11	20,785	"	11.34	0.0103		91.14		8.72	9.38	79,209	0.0219	794.5	2.34	6	Dunes
"	12	"	"	11.80	0.0109		87.60		9.33	9.99	81,461	0.0245	817.1	2.49	6	"
"	13	"	"	—	0.0143		—		—	—	—	—	—	4.72	4	"
"	14	"	"	—	0.0146		—		—	—	—	—	—	4.82	4	"
"	15	31,687	"	17.13	0.0056		91.96		10.79	7.70	98,928	0.0185	992.3	2.19	6	"
"	16	"	"	—	0.0123		—		—	—	—	—	—	3.98	3	"
"	17	"	"	—	0.0131		—		—	—	—	—	—	4.22	3	"
"	18	"	"	—	0.0111		—		—	—	—	—	—	4.67	3	"
"	19	"	"	—	0.0124		—		—	—	—	—	—	4.32	3	"
"	20	"	"	—	0.0131		—		—	—	—	—	—	4.67	3	"
"	21	"	"	—	0.0129		—		—	—	—	—	—	4.72	3	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE —27(cont.)

Author's references (1)	(2)	Discharge, Q cubic centimeters per second (3)	Width of flume, B centimeters (4)	Mean water depth, D centimeters (5)	Slope of bed, S (6)	Water temperature degrees centigrade (7)	Velocity centimeters per second Mean V_m (8)	Velocity centimeters per second Bottom V_b (9)	Hydraulic radius of bed, r_b centimeters (10)	Friction velocity, V^* centimeters per second (11)	Reynolds' Number, R (12)	Manning's n of bed, n_b (1) (13)	Unit discharge, q_b cubic centimeters per second per centimeter (14)	Rate of bed movement, G (2) grams per second per centimeter (15)	Duration of run minutes (16)	Bed condition (17)
SAND E (cont.)																
4E	22	31,687	20.12	—	0.0138	No Observations	—	No Observations	—	—	—	—	—	8.30	3	Dunes
"	23	"	"	—	0.0128		—		—	—	—	—	—	9.15	3	"
"	24	"	"	—	0.0141		—		—	—	—	—	—	9.24	3	—
"	25	5,154	30.48	—	0.0059		—		—	—	—	—	—	0.17	21	Dunes
"	26	"	"	2.87	0.0111		59.01		2.65	5.37	15,602	0.0159	156.5	0.62	10	—
"	27	"	"	2.65	0.0112		63.76		2.44	5.18	15,499	0.0140	155.5	0.62	16	—
"	28	"	"	2.47	0.0180		68.49		2.32	6.39	15,815	0.0159	158.6	1.44	8	—
"	29	"	"	2.35	0.0180		72.05		2.20	6.22	15,768	0.0146	158.2	1.44	8	—
"	30	"	"	2.83	0.0194		59.65		2.68	7.14	15,950	0.0209	160.0	1.64	9	—
"	31	"	"	—	0.0242		—		—	—	—	—	—	2.46	5	—
"	32	10,279	"	10.88	—		31.00		—	—	—	—	—	0.00	—	—
"	33	"	"	9.57	—		35.23		—	—	—	—	—	0.00	—	Dunes forming
"	34	"	"	7.35	0.0022		45.90		6.07	3.62	27,760	0.0158	278.4	0.10	61	Dunes
"	35	"	"	7.38	0.0025		45.72		6.22	3.90	28,344	0.0172	284.3	0.07	60	"
"	36	"	"	6.64	0.0044		50.75		5.85	5.03	29,610	0.0197	297.0	0.25	20	—
"	37	"	"	6.46	0.0044		52.18		5.67	4.95	29,493	0.0188	295.8	0.26	20	—
"	38	"	"	4.91	0.0087		68.73		4.36	6.10	29,869	0.0168	299.6	0.72	34	Transition
"	39	"	"	—	0.0128		—		—	—	—	—	—	1.74	9	"
"	40	"	"	3.44	0.0183		97.90		3.05	7.40	29,751	0.0135	298.4	3.41	5	"
"	41	"	"	3.35	0.0229		100.58		3.02	8.23	30,264	0.0146	303.6	5.51	4	"
"	42	20,785	"	18.84	—		36.21		—	—	—	—	—	—	—	Dunes
"	43	"	"	17.13	—		39.81		—	—	—	—	—	—	—	"
"	44	"	"	13.62	0.0019		50.05		10.61	4.45	52,929	0.0195	530.9	0.06	70	"
"	45	"	"	13.47	0.0018		50.63		10.33	4.27	52,160	0.0185	523.2	0.12	63	"
"	46	"	"	12.53	0.0029		54.44		10.24	5.40	55,585	0.0217	557.5	0.15	31	"
"	47	"	"	12.28	0.0026		55.50		9.78	4.99	54,139	0.0195	543.0	0.33	25	"
"	48	"	"	11.09	0.0046		61.45		9.39	6.51	57,516	0.0229	576.9	0.66	8	"
"	49	"	"	9.24	0.0048		73.82		7.41	5.91	54,514	0.0165	546.8	0.66	18	"
"	50	"	"	9.17	0.0047		74.34		7.32	5.81	54,217	0.0161	543.8	0.85	16	"
"	51	"	"	9.88	0.0073		69.04		8.60	7.84	59,163	0.0241	593.4	1.44	10	"
"	52	"	"	9.94	0.0074		68.64		8.66	7.93	59,237	0.0245	594.2	1.54	6	"
"	53	"	"	8.32	0.0083		81.96		7.04	7.57	57,535	0.0190	577.1	1.48	8	"
"	54	"	"	7.19	0.0119		94.79		6.16	8.48	58,187	0.0179	583.6	2.82	6	Transition
"	55	"	"	6.80	0.0123		100.31		5.76	8.34	57,616	0.0165	577.9	3.28	4	—
"	56	"	"	5.70	0.0146		119.63		4.69	8.20	55,986	0.0131	561.5	4.43	3	—
"	57	"	"	5.76	0.0150		118.38		4.79	8.39	56,476	0.0136	566.5	4.92	3	—
"	58	"	"	—	0.0161		—		—	—	—	—	—	7.22	2	Smooth
"	59	31,687	"	11.58	0.0052		89.76		8.69	6.66	77,742	0.0158	779.8	1.64	6	—
"	60	"	"	12.37	0.0059		84.00		9.82	7.54	82,199	0.0195	824.5	1.64	8	—
"	61	"	"	—	0.0115		—		—	—	—	—	—	5.58	3	—
"	62	"	"	—	0.0118		—		—	—	—	—	—	6.23	3	—
"	63	10,279	40.23	3.99	0.0067		63.98		3.63	4.88	23,137	0.0140	232.1	0.50	15	Dunes
"	64	"	"	3.93	0.0073	"	64.98		3.57	5.05	23,103	0.0142	231.7	0.50	10	"
"	65	"	"	2.96	0.0178		86.44		2.74	6.92	23,639	0.0141	237.1	2.31	5	—
"	66	20,785	"	7.28	0.0060		70.90		6.43	6.15	45,460	0.0175	456.0	0.82	9	Dunes
"	67	"	"	6.04	0.0110		85.59		5.43	7.65	46,294	0.0176	464.3	2.11	4	—
"	68	"	"	6.43	0.0112		80.35		5.85	8.02	46,880	0.0199	470.2	2.14	3	—
"	69	31,687	"	9.88	0.0058		79.74		8.44	6.93	67,123	0.0184	673.2	1.14	6	Dunes
"	70	"	"	9.66	0.0062		81.50		8.29	7.10	67,370	0.0184	675.7	1.24	4	"
"	71	"	"	—	0.0113		—		—	—	—	—	—	4.05	3	—
"	72	"	"	—	0.0122		—		—	—	—	—	—	4.25	3	—
SAND F																
4F	1	5,154	20.12	3.60	0.0129		71.23		3.11	6.27	22,079	0.0158	221.5	0.55	17	Smooth
"	2	"	"	3.93	0.0131		65.17		3.48	6.68	22,579	0.0187	226.5	0.60	23	"
"	3	"	"	3.11	0.0251		82.42		2.80	8.31	23,042	0.0178	231.1	2.58	11	"
"	4	"	"	3.23	0.0250		79.28		2.93	8.47	23,128	0.0189	232.0	2.63	8	"
"	5	10,279	"	6.31	0.0112		80.99		5.15	7.52	41,593	0.0181	417.2	1.29	17	"
"	6	"	"	6.22	0.0113		82.20		5.06	7.49	41,469	0.0177	415.9	1.29	12	"
"	7	"	"	5.36	0.0189		95.22		4.51	9.14	42,826	0.0183	429.5	3.98	6	—
"	8	"	"	5.18	0.0196		98.60		4.36	9.15	42,851	0.0176	429.8	3.53	10	—
"	9	20,785	"	10.55	0.0097		97.96		7.71	8.56	75,311	0.0182	755.4	1.84	9	Dunes
"	10	"	"	10.36	0.0100		99.70		7.56	8.61	75,138	0.0179	753.6	1.89	6	"
"	11	"	"	—	0.0168		—		—	—	—	—	—	5.12	3	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE—27(cont.)

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Slope of bed, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds' Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
							Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
							SAND F (cont.)									
4F	12	20,785	20.12	—	0.0175		—		—	—	—	—	—	5.37	3	Dunes
"	13	5,154	30.48	2.74	0.0136		61.63		2.56	5.84	15,730	0.0165	157.8	0.22	21	Smooth
"	14	"	"	2.38	0.0249		71.11		2.26	7.42	15.994	0.0177	160.4	1.38	7	"
"	15	"	"	2.44	0.0253		69.34		2.32	7.58	16.011	0.0187	160.6	1.44	7	"
"	16	10.279	"	4.88	0.0085		69.16		4.30	5.99	29,636	0.0164	297.3	0.31	18	"
"	17	"	"	4.91	0.0091		68.73		4.36	6.24	29,869	0.0172	299.6	0.33	20	"
"	18	"	"	3.90	0.0165		86.44		3.51	7.53	30,206	0.0160	303.0	1.54	14	"
"	19	"	"	3.96	0.0170		85.10		3.60	7.74	30.518	0.0167	306.1	1.67	10	"
"	20	"	"	4.27	0.0168		79.03		3.90	8.02	30.738	0.0189	308.3	1.84	8	"
"	21	"	"	—	0.0247		—		—	—	—	—	—	3.94	3	—
"	22	20.785	"	8.17	0.0077		83.48		6.80	7.16	56.571	0.0175	567.4	0.82	14	Dunes
"	23	"	"	8.08	0.0077		84.43		6.71	7.12	56,450	0.0171	566.2	0.82	12	"
"	24	"	"	6.61	0.0152		103.08		5.70	9.22	58,580	0.0177	587.6	3.22	5	"
"	25	"	"	6.43	0.0160		106.04		5.55	9.33	58.644	0.0173	588.2	3.74	5	"
"	26	31.687	"	10.06	0.0080		103.36		7.80	7.82	80.411	0.0158	806.5	1.74	5	"
"	27	"	"	10.45	0.0085		99.43		8.35	8.34	82.796	0.0177	830.4	1.84	5	"
"	28	"	"	—	0.0165		—		—	—	—	—	—	6.46	3	"
"	29	"	"	—	0.0167	No Observations	—	No Observations	—	—	—	—	—	6.86	3	"
"	30	10.279	40.23	3.54	0.0116		72.27		3.26	6.09	23,497	0.0152	235.7	0.52	7	Smooth
"	31	"	"	3.60	0.0121		71.02		3.35	6.31	23,742	0.0161	238.1	0.52	21	"
"	32	"	"	3.47	0.0205		73.52		3.29	8.14	24.131	0.0200	242.0	1.69	9	Transition
"	33	"	"	3.29	0.0207		77.60		3.11	7.94	24,054	0.0183	241.3	1.79	5	"
"	34	20,785	"	6.46	0.0083		79.95		5.73	6.83	45,674	0.0170	458.1	0.65	13	Dunes
"	35	"	"	6.37	0.0085		81.08		5.67	6.87	45,827	0.0168	459.6	0.67	12	"
"	36	"	"	6.55	0.0086		78.82		5.85	7.03	45,987	0.0178	461.3	0.67	12	"
"	37	"	"	5.36	0.0148		96.32		4.85	8.39	46,537	0.0168	466.8	2.54	3	—
"	38	"	"	5.49	0.0158		94.15		5.00	8.80	46,925	0.0181	470.7	2.63	4	—
"	39	31,687	"	8.38	0.0074		93.97		7.07	7.16	66,247	0.0157	664.5	1.24	12	Dunes
"	40	"	"	8.78	0.0078		89.70		7.56	7.60	67,601	0.0176	678.0	1.24	9	"
"	41	"	"	8.66	0.0084		90.98		7.50	7.86	68,013	0.0180	682.2	1.47	6	"
"	42	"	"	—	0.0155		—		—	—	—	—	—	4.67	2	"
"	43	"	"	—	0.0160		—		—	—	—	—	—	5.17	2	"
								SAND G								
4G	1	10,279	20.12	6.04	0.0111		84.64		4.85	7.26	40,894	0.0165	410.2	0.55	15	—
"	2	"	"	5.67	0.0144		90.10		4.66	8.11	41,888	0.0173	420.1	1.24	12	—
"	3	"	"	5.85	0.0148		87.33		4.88	8.41	42,464	0.0186	425.9	1.39	15	—
"	4	"	"	5.33	0.0182		95.80		4.45	8.91	42,503	0.0177	426.3	2.34	6	—
"	5	"	"	5.33	0.0190		95.80		4.48	9.14	42,800	0.0182	429.3	2.49	8	—
"	6	"	"	4.88	0.0256		104.79		4.18	10.24	43,629	0.0184	437.6	4.97	3	—
"	7	"	"	4.82	0.0270		106.07		4.15	10.48	43,834	0.0186	439.7	5.22	3	—
"	8	20,785	"	11.37	0.0068		90.86		7.80	7.21	70,686	0.0166	709.0	0.42	14	—
"	9	"	"	11.09	0.0070		93.15		7.56	7.20	70,201	0.0161	704.1	0.55	23	—
"	10	"	"	10.42	0.0095		99.12		7.53	8.38	74,404	0.0175	746.3	1.29	11	—
"	11	"	"	9.81	0.0119		105.28		7.29	9.22	76,467	0.0181	767.0	2.39	7	—
"	12	"	"	9.88	0.0119		104.64		7.35	9.26	76.639	0.0183	768.7	2.44	11	—
"	13	"	"	8.90	0.0171		116.10		6.86	10.72	79.383	0.0189	796.2	5.17	5	—
"	14	"	"	7.96	0.0243		129.84		6.31	12.26	81,671	0.0191	819.2	10.44	3	—
"	15	"	"	8.05	0.0235		128.44		6.37	12.12	81,571	0.0190	818.2	10.88	3	—
"	16	31,687	"	17.01	0.0062		92.60		11.10	8.21	102.433	0.0197	1027.4	0.60	18	—
"	17	"	"	14.02	0.0098		112.35		9.42	9.51	105,495	0.0183	1058.1	2.44	6	—
"	18	"	"	13.75	0.0102		114.57		9.21	9.60	105,147	0.0180	1054.6	2.68	6	—
"	19	"	"	12.62	0.0135		124.85		8.81	10.80	109,651	0.0184	1099.8	4.67	4	—
"	20	"	"	12.53	0.0132		125.73		8.63	10.57	108.131	0.0179	1084.6	5.67	4	—
"	21	"	"	11.40	0.0197		138.20		8.38	12.73	115.493	0.0195	1158.4	10.54	3	—
"	22	"	"	11.52	0.0195		136.70		8.47	12.73	115.480	0.0197	1158.3	10.69	3	—
"	23	"	"	10.79	0.0240		146.00		8.11	13.81	118,023	0.0199	1183.8	15.46	3	—
"	24	"	"	•	0.0236		—		—	—	—	—	—	16.45	3	—
"	25	10.279	30.48	4.36	0.0127		77.36		3.90	6.97	30,088	0.0168	301.8	0.33	20	Smooth
"	26	"	"	4.24	0.0148		79.61		3.84	7.47	30,479	0.0174	305.7	0.69	15	"
"	27	"	"	4.15	0.0161		81.35		3.75	7.69	30,407	0.0175	305.0	0.82	12	"
"	28	"	"	4.30	0.0162		78.46		3.93	7.90	30,758	0.0187	308.5	0.92	18	"
"	29	"	"	4.02	0.0176		83.82		3.66	7.95	30,569	0.0174	306.6	1.12	12	"
"	30	"	"	3.93	0.0209		85.77		3.60	8.59	30.759	0.0184	308.5	1.64	9	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE — 27 (cont.)

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Slope of bed, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds' Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
							Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
								SAND G (cont.)								
4G	31	10,279	30.48	3.47	0.0274	No Observations	97.05	No Observations	3.20	9.27	30,963	0.0172	310.6	3.18	5	—
"	32	20,785	"	8.29	0.0078		82.27		6.95	7.29	56,998	0.0182	511.7	0.36	42	Smooth
"	33	"	"	7.56	0.0086		90.22		6.25	7.26	56,161	0.0162	563.7	0.66	15	"
"	34	"	"	7.56	0.0095		90.22		6.34	7.69	57,028	0.0172	572.0	0.82	15	"
"	35	"	"	7.65	0.0097		89.72		6.46	7.84	57,417	0.0178	575.9	0.85	11	"
"	36	"	"	7.16	0.0127		95.79		6.16	8.76	58,433	0.0185	586.1	1.67	10	"
"	37	"	"	6.52	0.0169		104.55		5.67	9.69	59,092	0.0184	592.1	3.28	5	"
"	38	"	"	5.79	0.0230		117.74		5.09	10.71	59,757	0.0177	599.3	6.20	4	—
"	39	"	"	5.82	0.0237		117.13		5.12	10.91	59,803	0.0181	599.8	6.96	3	—
"	40	31,687	"	11.86	0.0064		87.69		9.42	7.69	82,339	0.0189	825.9	0.33	20	Smooth
"	41	"	"	10.88	0.0066		95.52		8.38	7.37	79,826	0.0163	800.7	0.78	15	—
"	42	"	"	10.94	0.0067		95.01		8.47	7.46	80,261	0.0166	805.0	0.82	17	—
"	43	"	"	9.88	0.0091		105.28		7.93	8.68	83,184	0.0173	834.3	1.74	6	—
"	44	"	"	9.94	0.0090		104.64		7.86	8.33	82,043	0.0166	822.9	1.77	7	—
"	45	"	"	9.39	0.0122		110.73		7.71	9.61	85,129	0.0181	853.8	3.28	4	—
"	46	"	"	9.36	0.0131		111.10		7.74	9.97	85,757	0.0188	860.1	3.38	4	—
"	47	"	"	8.38	0.0178		124.02		7.04	11.09	87,061	0.0184	873.2	7.02	3	—
"	48	"	"	7.68	0.0204		135.53		6.40	11.32	86,494	0.0169	867.5	9.74	3	—
"	49	"	"	7.71	0.0221		134.81		6.52	11.89	87,674	0.0179	879.4	10.17	3	—
"	50	10,279	40.23	3.51	0.0190		72.88		3.32	7.87	24,139	0.0195	242.1	0.60	12	—
"	51	"	"	3.17	0.0197		80.59		2.99	7.60	24,000	0.0168	240.7	0.65	9	—
"	52	"	"	3.29	0.0225		77.60		3.11	8.28	24,054	0.0191	241.3	1.22	10	—
"	53	"	"	3.20	0.0234		79.83		3.02	8.32	24,021	0.0186	240.9	1.77	10	—
"	54	"	"	2.83	0.0302		90.10		2.68	8.91	24,093	0.0173	241.7	2.36	3	—
"	55	"	"	2.96	0.0310		86.44		2.80	9.23	24,166	0.0188	242.4	3.06	4	—
"	56	20,785	"	6.40	0.0082		80.71		5.67	6.75	45,617	0.0166	457.5	0.22	21	—
"	57	"	"	6.40	0.0082		80.71		5.67	6.75	45,617	0.0166	457.5	0.30	18	—
"	58	"	"	5.91	0.0108		87.36		5.30	7.50	46,197	0.0168	463.4	0.60	13	—
"	59	"	"	6.10	0.0114		84.73		5.52	7.85	46,606	0.0183	467.5	0.67	13	—
"	60	"	"	5.88	0.0141		87.81		5.36	8.61	46,960	0.0192	471.0	1.29	6	—
"	61	"	"	5.21	0.0182		99.12		4.76	9.21	46,991	0.0179	471.3	2.54	4	—
"	62	"	"	4.97	0.0244		103.97		4.60	10.49	47,704	0.0193	478.5	4.97	3	—
"	63	31,687	"	9.05	0.0071		87.02		7.77	7.36	67,430	0.0176	676.3	0.35	19	—
"	64	"	"	8.23	0.0090		95.71		7.10	7.92	67,770	0.0170	679.7	1.14	4	—
"	65	"	"	7.96	0.0107		99.00		6.95	8.54	68,589	0.0177	688.0	1.67	6	—
"	66	"	"	7.56	0.0131		104.18		6.68	9.26	69,332	0.0181	695.4	2.36	3	—
"	67	"	"	7.47	0.0140		105.46		6.61	9.53	69,542	0.0184	697.5	2.73	4	—
"	68	"	"	7.01	0.0183		112.35		6.28	10.62	70,334	0.0190	705.5	4.97	3	—
"	69	"	"	6.13	0.0217		128.56		5.46	10.78	69,932	0.0165	701.4	7.01	3	—
"	70	"	"	6.16	0.0226		127.92		5.49	11.03	69,967	0.0170	701.8	7.51	3	—
								SAND H								
4 H	1	10,279	20.12	5.61	0.0149		91.14		4.63	8.23	42,099	0.0173	422.3	0.46	21	—
"	2	"	"	5.61	0.0158		91.14		4.66	8.50	42,372	0.0179	425.0	0.60	16	—
"	3	"	"	5.58	0.0180		91.59		4.72	9.13	43,138	0.0192	432.7	0.84	18	—
"	4	"	"	5.27	0.0184		96.90		4.39	8.90	42,402	0.0174	425.3	1.09	14	—
"	5	"	"	5.09	0.0243		100.40		4.36	10.19	43,633	0.0192	437.6	2.53	5	—
"	6	"	"	5.27	0.0247		96.90		4.57	10.52	44,170	0.0208	443.0	2.78	6	—
"	7	20,785	"	10.52	0.0090		98.27		7.50	8.14	73,463	0.0172	736.8	0.39	18	—
"	8	"	"	10.61	0.0095		97.38		7.71	8.48	74,865	0.0181	750.9	0.55	17	—
"	9	"	"	10.15	0.0110		101.77		7.50	8.99	76,079	0.0184	763.1	0.99	17	—
"	10	"	"	10.49	0.0119		98.54		8.05	9.69	79,058	0.0207	793.0	1.09	15	—
"	11	"	"	9.75	0.0150		105.92		7.62	10.59	80,470	0.0208	807.1	2.53	8	—
"	12	"	"	9.45	0.0151		109.33		7.29	10.39	79,409	0.0196	796.5	2.58	8	—
"	13	"	"	8.81	0.0202		117.32		7.01	11.78	81,995	0.0206	822.4	5.22	4	—
"	14	"	"	7.62	0.0269		135.58		6.07	12.65	81,997	0.0187	822.4	10.39	3	—
"	15	"	"	7.71	0.0292		133.96		6.25	13.38	83,448	0.0201	837.0	11.03	3	—
"	16	31,687	"	15.30	0.0074		102.96		9.85	8.45	101,061	0.0178	1013.6	0.60	16	—
"	17	"	"	15.54	0.0081		101.32		10.52	9.14	106,229	0.0198	1065.5	0.50	20	—
"	18	"	"	15.33	0.0089		102.72		10.58	9.61	108,301	0.0205	1086.3	0.60	21	—
"	19	"	"	14.33	0.0103		109.94		9.91	10.00	108,581	0.0198	1089.1	1.29	15	—
"	20	"	"	13.47	0.0126		116.92		9.57	10.88	111,569	0.0201	1119.0	2.63	13	—
"	21	"	"	13.32	0.0128		118.26		9.45	10.89	111,410	0.0199	1117.4	2.68	10	—
"	22	"	"	13.62	0.0133		115.61		9.91	11.37	114,180	0.0214	1145.2	2.63	9	—

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE —27(cont.)

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Slope of bed, S	Water temperature degrees centigrade	Velocity centimeters per second Mean V_m	Velocity centimeters per second Bottom V_b	Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds' Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, $G^{(2)}$ grams per second per centimeter	Duration of run minutes	Bed condition
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND H (cont.)																
4H	23	31,687	20.12	11.92	0.0165		132.16		8.53	11.75	112,448	0.0189	1127.9	4.87	3	—
"	24	"	"	12.13	0.0163		129.84		8.75	11.83	113,244	0.0194	1135.8	5.27	6	—
"	25	"	"	11.95	0.0162		131.83		8.50	11.62	111,773	0.0187	1121.1	5.62	3	—
"	26	"	"	10.36	0.0231		152.00		7.56	13.09	114.553	0.0179	1149.0	10.39	3	—
"	27	"	"	10.18	0.0238		154.75		7.38	13.12	113,803	0.0175	1141.4	10.39	3	—
SAND C																
4I	1	20,785	30.48	7.07	0.0058		96.44		5.27	5.48	50.701	0.0111	508.5	2.76	4	Transition
"	2	"	"	7.35	0.0058		92.84		5.58	5.63	51,631	0.0120	517.9	1.48	4	"
"	3	"	"	5.91	0.0099		115.34		4.60	6.68	52,920	0.0111	530.8	6.36	3	—
"	4	26,136	"	8.23	0.0058		104.21		5.85	5.77	60,802	0.0110	609.8	3.38	3	Transition
"	5	"	"	8.60	0.0062		99.76		6.40	6.24	63,665	0.0126	638.6	3.38	3	"
"	6	"	"	7.10	0.0109		120.73		5.52	7.68	66,408	0.0125	666.1	9.19	2	—
"	7	31,687	"	9.51	0.0057		109.33		6.52	6.04	71,103	0.0112	713.2	3.87	3	Transition
"	8	"	"	9.30	0.0066		111.83		6.61	6.54	73,743	0.0119	739.6	4.23	3	—
"	9	20,785	36.58	6.77	0.0051		83.97		5.49	4.94	45.928	0.0123	460.7	2,02	3	Transition
"	10	"	"	6.55	0.0060		86.72		5.40	5.63	46,645	0.0128	467.9	2.02	3	"
"	11	"	"	5.27	0.0105		107.78		4.42	6.75	47.497	0.0119	476.4	5.96	3	"
"	12	"	"	5.33	0.0107	No Observations	106.53	No Observations	4.51	6.88	47.912	0.0123	480.6	6.10	3	"
"	13	26,136	"	7.07	0.0065		101.04		5.58	5.96	56,191	0.0117	563.6	2.84	3	"
"	14	"	"	6.40	0.0106		111.65		5.33	7.45	59.376	0.0131	595.5	7.27	3	"
"	15	"	"	6.13	0.0101		116.65		4.97	7.02	57,779	0.0116	579.5	7.49	3	"
"	16	28.912	"	7.62	0.0057		103.72		5.79	5.69	59,884	0.0109	600.6	2.93	3	"
"	17	"	"	7.99	0.0054		98.97		6.10	5.68	60,152	0.0115	603.3	2.98	4	"
"	18	"	"	6.00	0.0120		131.64		4.82	7.53	63,208	0.0110	634.0	8.88	3	Smooth
"	19	31,687	"	8.20	0.0062		105.67		6.28	6.18	66.152	0.0118	663.5	3.12	4	Transition
"	20	"	"	8.20	0.0061		105.67		6.28	6.13	66,152	0.0117	663.5	3.36	4	"
"	21	"	"	6.83	0.0100		126.89		5.36	7.25	67.860	0.0112	680.6	7.98	3	Smooth
"	22	"	"	7.04	0.0103		123.05		5.64	7.55	69,180	0.0121	693.9	8.91	3	"
"	23	20,785	42.67	6.07	0.0063		80.31		5.27	5.71	42,220	0.0139	423.5	1.73	4	Transition
"	24	"	"	5.97	0.0059		81.53		5.15	5.46	41,870	0.0131	420.0	1.76	4	"
"	25	"	"	4.82	0.0104		101.13		4.21	6.55	42,408	0.0122	425.4	5.04	3	Smooth
"	26	"	"	4.60	0.0107		105.83		3.99	6.47	42,132	0.0114	422.6	5.30	3	"
"	27	26,136	"	7.16	0.0051		85.50		5.97	5.47	50,925	0.0128	510.8	1.85	4	Transition
"	28	"	"	7.22	0.0057		84.80		6.13	5.85	51,793	0.0139	519.5	1.73	4	"
"	29	"	"	5.36	0.0103		114.18		4.54	6.77	51,706	0.0113	518.6	6.54	3	Smooth
"	30	"	"	5.33	0.0104		114.82		4.51	6.78	51,640	0.0113	518.0	6.96	3	"
"	31	28,912	"	7.56	0.0058		89.64		6.31	5.99	56.385	0.0135	565.5	2.27	4	—
"	32	"	"	5.52	0.0103		122.80		4.57	6.80	55,976	0.0106	561.4	7.48	3	Smooth
"	33	"	"	5.49	0.0108		123.50		4.57	6.96	56,295	0.0108	564.6	7.57	3	"
"	34	31,687	"	7.74	0.0057		95.92		6.31	5.94	60,335	0.0125	605.2	2.44	4	—
"	35	"	"	7.04	0.0061		105.46		5.64	5.81	59,291	0.0109	594.7	3.05	4	—
"	36	"	"	6.49	0.0097		114.39		5.46	7.20	62.224	0.0124	624.1	7.62	3	Smooth
"	37	"	"	6.55	0.0101		113.32		5.55	7.41	62.671	0.0129	628.6	7.90	3	"
"	38	"	"	6.19	0.0107		120.00		5.21	7.40	62,357	0.0120	625.4	7.31	3	"
"	39	20,785	48.77	5.82	0.0060		73.21		5.21	5.54	38,043	0.0148	381.6	1.44	4	—
"	40	"	"	3.69	0.0114		115.55		3.23	6.01	37,222	0.0094	373.3	4.84	3	Smooth
"	41	"	"	3.72	0.0112		114.60		3.26	5.99	37.259	0.0094	373.7	5.50	3	"
"	42	26.136	"	7.10	0.0045		75.47		6.16	5.21	46,328	0.0139	464.7	1.68	4	Dunes
"	43	"	"	6.16	0.0046		87.05		5.15	4.82	44,705	0.0108	448.4	1.42	5	"
"	44	"	"	6.83	0.0050		78.49		5.94	5.40	46,514	0.0137	466.5	1.35	4	"
"	45	"	"	4.91	0.0105		109.21		4.30	6.65	46,798	0.0115	469.4	6.13	3	Smooth
"	46	"	"	4.91	0.0107		109.21		4.30	6.72	46,798	0.0116	469.4	5.74	3	"
"	47	28,912	"	7.41	0.0039		80.04		6.19	4.86	49,373	0.0122	495.2	1.35	4	—
"	48	"	"	7.44	0.0047		79.71		6.40	5.43	50,869	0.0138	510.2	1.50	4	—
"	49	"	"	7.07	0.0051		83.85		6.07	5.51	50,711	0.0132	508.6	1.64	4	—
"	50	"	"	5.15	0.0106		115.09		4.48	6.83	51.418	0.0113	515.7	6.38	3	—
"	51	31.687	"	6.92	0.0049		93.91		5.73	5.25	53,649	0.0111	538.1	1.70	4	Transition
"	52	"	"	7.13	0.0047		91.10		5.91	5.22	53,706	0.0114	538.7	1.87	4	"
"	53	"	"	7.10	0.0055		91.50		6.01	5.69	54.782	0.0125	549.5	2.01	4	"
"	54	"	"	5.73	0.0099		113.39		4.94	6.92	55.825	0.0118	559.9	6.81	3	—
"	55	20,785	54.86	5.30	0.0061		71.45		4.86	5.39	34,649	0.0145	347.5	1.26	4	Dunes
"	56	"	"	5.30	0.0060		71.45		4.85	5.34	34,521	0.0144	346.3	1.31	4	"
"	57	"	"	4.18	0.0104		90.71		3.81	6.23	34,458	0.0127	345.6	3.72	3	Smooth

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE—27 (cont.)

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Slope of bed, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds' Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
							Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND C (cont.)																
41	58	20,785	54.86	3.96	0.0106	No Observations	95.62	No Observations	3.60	6.12	34,292	0.0118	344.0	3.70	3	Smooth
"	59	26,136	"	6.28	0.0053		75.86		5.61	5.40	42,415	0.0140	425.4	1.37	4	Dunes
"	60	"	"	6.22	0.0058		76.63		5.58	5.63	42,616	0.0145	427.4	1.35	4	"
"	61	"	"	4.79	0.0104		99.55		4.33	6.64	42,956	0.0126	430.9	4.70	3	Smooth
"	62	"	"	4.63	0.0104		102.84		4.15	6.50	42,509	0.0120	426.4	4.98	3	"
"	63	28,912	"	6.83	0.0051		77.18		6.07	5.51	46,677	0.0143	468.2	1.26	4	Dunes
"	64	"	"	6.92	0.0052		76.17		6.16	5.60	46,758	0.0148	469.0	1.39	4	"
"	65	"	"	6.86	0.0057		76.84		6.16	5.87	47,168	0.0153	473.1	1.39	4	"
"	66	"	"	4.72	0.0100		111.53		4.18	6.40	46,436	0.0108	465.0	5.89	3	Smooth
"	67	"	"	4.82	0.0101		109.42		4.27	6.50	46,550	0.0112	466.9	5.61	3	"
"	68	31,687	"	7.32	0.0042		78.94		6.34	5.11	49,898	0.0131	500.5	1.20	4	Dunes
"	69	"	"	7.41	0.0047		77.97		6.52	5.48	50,708	0.0142	508.6	1.35	4	"
"	70	"	"	4.88	0.0105		118.41		4.27	6.63	50,375	0.0106	505.3	6.84	3	Smooth
"	71	"	"	5.09	0.0105		113.48		4.48	6.79	50,698	0.0114	508.5	7.02	3	"
"	72	20,785	59.74	4.48	0.0061		77.66		4.08	4.94	31,621	0.0119	317.2	1.39	4	Transition
"	73	"	"	4.45	0.0069		78.18		4.08	5.26	31,833	0.0126	319.3	1.47	4	"
"	74	"	"	3.57	0.0105		97.57		3.26	5.79	31,723	0.0107	318.2	3.95	3	Smooth
"	75	"	"	3.75	0.0109		92.78		3.48	6.09	32,145	0.0120	322.4	3.87	3	"
"	76	"	"	3.72	0.0112		93.57		3.44	6.15	32,130	0.0120	322.3	4.18	3	—
"	77	26,136	"	5.36	0.0062		81.53		4.85	5.43	39,391	0.0128	395.1	1.62	3	Transition
"	78	"	"	4.36	0.0102		100.37		3.99	6.32	39,958	0.0118	400.8	4.67	3	—
"	79	28,912	"	5.91	0.0050		81.84		5.24	5.07	42,781	0.0121	429.1	1.42	4	Transition
"	80	"	"	6.10	0.0057		79.40		5.49	5.54	43,429	0.0137	435.6	1.46	4	"
"	81	"	"	5.88	0.0054		82.27		5.24	5.27	43,005	0.0125	431.3	1.74	3	"
"	82	"	"	4.30	0.0109		112.59		3.84	6.41	43,106	0.0105	432.4	5.74	3	"
"	83	"	"	4.39	0.0109		110.28		3.96	6.51	43,562	0.0110	436.9	5.89	3	"
"	84	31,687	"	6.52	0.0045		81.32		5.73	5.03	46,457	0.0123	466.0	1.37	4	Dunes
"	85	"	"	6.77	0.0057		78.39		6.10	5.84	47,644	0.0149	477.9	1.41	4	Transition
"	86	"	"	6.68	0.0052		79.46		5.97	5.52	47,327	0.0139	474.7	1.57	4	"
"	87	"	"	4.57	0.0100		116.01		4.05	6.31	46,889	0.0102	470.3	5.71	3	Smooth
"	88	"	"	4.48	0.0100		118.38		3.96	6.23	46,762	0.0098	469.0	6.08	3	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 28
BED-LOAD EXPERIMENTS OF C. H. MACDOUGALL
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds' Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G(2) grams per second per centimeter	Duration of run minutes	Bed condition
Table	Reading						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND I																
45	1	No Observations	60.96	1.95	0.00333	No Observations	31.90	No Observations		2.52	6,221	0.0131	62.2	0.0256	No Observations	No Observations
"	2		"	2.76	"		38.04			3.00	10,499	0.0140	105.0	0.0765		
"	3		"	3.36	"		42.02			3.31	14,119	0.0143	141.2	0.1298		
"	4		"	3.73	"		44.08			3.49	16,442	0.0145	164.4	0.0657		
"	5		"	4.40	"		48.14			3.79	21,182	0.0149	211.8	0.2480		
"	6		"	4.50	"		48.93			3.83	22,019	0.0150	220.2	0.2571		
"	7		"	5.30	"		53.64			4.16	28,429	0.0152	284.3	0.3514		
"	8		"	5.20	"		53.25			4.12	27,690	0.0152	276.9	0.2852		
"	9		"	5.30	"		53.47			4.16	28,339	0.0153	283.4	0.2604		
"	10		"	5.40	"		53.17			4.20	28,712	0.0155	287.1	0.2852		
"	11		"	6.00	"		56.52			4.43	33,912	0.0157	339.1	0.3059		
"	12		"	3.60	"		45.42			3.43	16,351	0.0139	163.5	0.1447		
"	13		"	6.20	"		57.24			4.50	35,489	0.0158	354.9	0.4010		
"	14		"	4.50	"		48.73			3.83	21,929	0.0151	219.3	0.2232		
"	1		"	4.04	0.00167		37.48			2.57	15,142	0.0129	151.4	0.0269		
"	2		"	4.10	"		40.34			2.59	16,539	0.0121	165.4	0.0384		
"	3		"	5.50	"		46.11			3.00	25,361	0.0128	253.6	0.0947		
"	4		"	5.60	"		45.29			3.03	25,362	0.0132	253.6	0.1100		
"	5		"	7.40	"		48.46			3.48	35,860	0.0149	358.6	0.1761		
"	6		"	8.65	"		51.02			3.76	44,132	0.0157	441.3	0.2716		
"	7		"	8.15	"		48.67			3.65	39,666	0.0158	396.7	0.1922		
"	1		"	6.07	0.00111		41.94			2.57	25,458	0.0123	254.6	0.0550		
"	2		"	6.58	"		44.06			2.68	28,991	0.0124	289.9	0.0699		
"	3		"	7.80	"		47.28			2.91	36,878	0.0129	368.8	0.0744		
"	4		"	10.06	"		49.87			3.31	50,169	0.0145	501.7	0.1157		
"	5		"	12.56	"		48.08			3.70	60,388	0.0174	603.9	0.1521		
"	6		"	6.49	"		45.52			2.66	29,542	0.0119	295.4	0.0488		
SAND II																
45	1	No Observations	60.96	3.26	0.00333	No Observations	44.45	No Observations		3.27	14,491	0.0133	144.9	0.0806	No Observations	No Observations
"	2		"	4.69	"		52.09			3.92	24,430	0.0145	244.3	0.2369		
"	3		"	4.30	"		51.86			3.75	22,300	0.0136	223.0	0.1521		
"	4		"	4.91	"		52.97			4.02	26,008	0.0146	260.1	0.2563		
"	5		"	3.44	"		44.83			3.36	15,421	0.0137	154.2	0.0996		
"	1		"	5.52	0.00167		42.57			3.01	23,499	0.0139	235.0	0.0550		
"	2		"	6.34	"		46.75			3.22	29,640	0.0139	296.4	0.0889		
"	3		"	4.88	"		43.79			2.83	21,370	0.0124	213.7	0.0310		
"	4		"	7.65	"		53.07			3.54	40,599	0.0139	406.0	0.1339		
"	5		"	11.19	"		58.11			4.28	65,025	0.0163	650.3	0.2108		
"	6		"	9.69	"		57.05			3.98	55,281	0.0151	552.8	0.1654		
"	1		"	5.76	0.00111		39.67			2.50	22,850	0.0125	228.5	0.0157		
"	2		"	6.86	"		43.06			2.73	29,539	0.0130	295.4	0.0211		
"	3		"	8.26	"		45.56			3.00	37,633	0.0139	376.3	0.0442		
"	4		"	10.24	"		52.35			3.34	53,606	0.0140	536.1	0.0761		
"	5		"	12.83	"		55.18			3.73	70,796	0.0154	707.9	0.1447		
"	6		"	13.17	"		55.94			3.79	73,673	0.0154	736.7	0.1203		
"	7		"	13.59	"		58.11			3.85	78,971	0.0152	789.7	0.1414		
"	8		"	14.02	"		56.33			3.91	78,975	0.0160	789.7	0.1819		
"	9		"	12.10	"		54.51			3.63	65,957	0.0150	659.6	0.1141		
"	10		"	14.63	"		66.04			3.99	96,617	0.0140	966.2	0.1468		
SAND III																
45	1	No Observations	60.96	4.45	0.00333	No Observations	51.98	No Observations		3.81	23,131	0.0139	231.3	0.0860	No Observations	No Observations
"	2		"	5.64	"		58.14			4.29	32,791	0.0146	327.9	0.1761		
"	3		"	6.95	"		68.17			4.76	47,378	0.0143	473.8	0.6242		
"	4		"	6.74	"		58.58			4.69	39,483	0.0163	394.8	0.3741		
"	5		"	5.46	"		54.10			4.22	29,539	0.0154	295.4	0.2315		
"	6		"	5.33	"		54.90			4.17	29,262	0.0149	292.6	0.2013		
"	7		"	6.55	"		57.45			4.62	37,630	0.0164	376.3	0.3472		
"	8		"	6.95	"		57.48			4.76	39,949	0.0170	399.5	0.3266		
"	9		"	6.64	"		57.65			4.66	38,280	0.0164	382.8	0.3431		
"	1		"	6.80	0.00167		47.68			3.34	32,422	0.0143	324.2	0.0723		
"	2		"	7.83	"		46.99			3.58	36,793	0.0160	367.9	0.0471		
"	3		"	8.35	"		48.40			3.70	40,414	0.0161	404.1	0.0736		
"	4		"	9.85	"		53.86			4.02	53,052	0.0162	530.5	0.1067		

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 28 (Continued)
BED-LOAD EXPERIMENTS OF C.H. MACDOUGALL
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b ⁽¹⁾	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G⁽²⁾ grams per second per centimeter	Duration of run minutes	Bed condition
Table	Reading						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
							SAND III (Continued)									
45	5	No Observations	60.96	10.97	0.00167	No Observations	58.86	No Observations		4.24	64,569	0.0159	645.7	0.1654	No Observations	No Observations
"	6		"	12.34	"		58.80			4.50	72,559	0.0172	725.6	0.2075		
"	7		"	12.56	"		61.02			4.54	76,641	0.0168	766.4	0.2241		
"	8		"	12.86	"		65.96			4.59	84,825	0.0158	848.2	0.2389		
"	9		"	11.00	"		56.59			4.24	62,249	0.0166	622.5	0.1517		
"	10		"	9.63	"		54.98			3.97	52,946	0.0156	529.5	0.0922		
"	11		"	8.66	"		51.17			3.77	44,313	0.0156	443.1	0.0868		
"	12		"	8.84	"		48.55			3.80	42,918	0.0167	429.2	0.0794		
"	1		"	12.44	0.00111		52.50			3.68	65,310	0.0158	653.1	0.0806		
"	2		"	13.35	"		55.33			3.81	73,866	0.0158	738.6	0.0980		
"	3		"	14.48	"		61.60			3.97	89,197	0.0149	891.9	0.1124		
"	4		"	15.09	"		65.26			4.05	98,477	0.0145	984.8	0.1207		
"	5		"	15.91	"		65.98			4.16	104,974	0.0148	1049.8	0.1492		

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 29
BED-LOAD EXPERIMENTS OF S.D. CHYN
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Author's references: Table (1)	Author's references: Reading (2)	Discharge, Q cubic centimeters per second (3)	Width of flume, B centimeters (4)	Mean water depth, D centimeters (5)	Water surface slope, S (6)	Water temperature degrees centigrade (7)	Velocity centimeters per second: Mean V_m (8)	Velocity centimeters per second: Bottom V_b (9)	Hydraulic radius of bed, r_b centimeters (10)	Friction velocity, V^* centimeters per second (11)	Reynolds Number, R (12)	Manning's n of bed, n_b (1) (13)	Unit discharge, q_b cubic centimeters per second per centimeter (14)	Rate of bed movement, G (2) grams per second per centimeter (15)	Duration of run minutes (16)	Bed condition (17)
							SAND 3									
I-IV	1		60.96	5.38	0.00152	22.5	37.5			2.83	21,417	0.0149	202	0.0279		Smooth
•	2		"	5.64	0.00157	21.2	39.8			2.95	23,094	0.0146	224	0.0379		Dunes < 0.5 cm.
•	3	No Observations	"	6.09	0.00161	20.2	41.3	No Observations		3.10	25,177	0.0150	252	0.0484	No Observations	" " " "
•	4		"	6.98	0.00157	18.9	44.3			3.28	29,963	0.0151	308	0.0654		" " 1.0 "
•	5		"	10.07	0.00200	18.5	58.6			4.44	56,632	0.0165	590	0.2034		" > 2.0 "
•	6		"	5.67	0.00185	18.4	43.4			3.21	23,526	0.0146	246	0.0719		" < 0.5 "
•	7		"	5.21	0.00247	21.0	47.6			3.55	25,357	0.0146	247	0.1426		" " " "
•	9		"	4.68	0.00300	22.2	51.8			3.71	25,518	0.0138	243	0.1819		" " 1.0 "
•	10		"	5.90	0.00146	22.2	43.7			2.91	27,140	0.0132	258	0.0626		" " 0.5 "
•	11		"	6.32	0.00120	21.8	40.4			2.73	26,624	0.0136	255	0.0246		Smooth
•	12		"	5.49	0.00200	21.8	45.9			3.28	26,276	0.0141	252	0.1199		Dunes < 1.0 cm.
•	13		"	5.51	0.00181	22.4	45.6			3.13	26,588	0.0135	251	0.0934		" " " "
							SAND 2									
I-IV	14		60.96	6.29	0.00238	22.4	50.4			3.83	33,547	0.0151	317	0.1108		Dunes < 2.0 cm.
•	15	No Observations	"	6.34	0.00206	24.8	48.4	No Observations		3.58	34,324	0.0149	307	0.1005	No Observations	" " 1.0 "
•	16		"	7.00	0.00150	23.9	44.1			3.21	33,775	0.0150	309	0.0568		" " 2.0 "
•	17		"	7.27	0.00133	25.0	42.9			3.08	35,043	0.0148	312	0.0518		" " " "
•	18		"	7.35	0.00110	23.0	42.2			2.82	33,352	0.0138	310	0.0382		" " 1.0 "
•	19		"	5.06	0.00159	24.7	40.7			2.81	22,985	0.0134	206	0.0279		" " " "
•	20		"	5.83	0.00163	27.0	43.6			3.05	29,834	0.0139	255	0.0551		" " 2.0 "
•	21		"	6.80	0.00169	26.0	45.6			3.36	35,600	0.0152	310	0.0773		" > " "
•	22		"	7.80	0.00168	26.6	47.0			3.58	42,628	0.0159	367	0.1162		" " " "
•	23		"	8.91	0.00178	26.5	55.0			3.94	56,850	0.0153	490	0.1488		" " " "
							SAND 1									
I-IV	24		60.96	6.08	0.00247	23.6	51.5			3.84	34,109	0.0149	313	0.2249		Dunes < 2.0 cm
•	25	No Observations	"	6.51	0.00191	23.6	48.2	No Observations		3.49	34,181	0.0147	314	0.1629	No Observations	" " 1.0 "
•	26		"	6.90	0.00145	27.0	45.2			3.13	36,606	0.0142	312	0.0777		" " " "
•	27		"	7.13	0.00129	26.9	43.3			3.00	36,193	0.0143	309	0.0577		" " " "
•	28		"	7.24	0.00111	25.5	42.4			2.81	38,372	0.0137	307	0.0305		" " " "
•	29		"	5.78	0.00160	24.5	44.1			3.01	28,354	0.0135	255	0.0707		" " " "
•	30		"	5.04	0.00163	25.0	41.2			2.84	23,331	0.0134	208	0.0350		" " " "
•	32		"	6.65	0.00161	24.0	47.0			3.24	34,346	0.0140	313	0.0909		" " 2.0 "
•	33		"	7.52	0.00163	24.6	48.8			3.47	40,866	0.0148	367	0.1199		" " " "
•	34		"	9.09	0.00166	24.8	55.3			3.85	56,228	0.0149	503	0.1550		" > " "

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 30
BED-LOAD EXPERIMENTS OF A.L. JORISSEN
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Author's references							Velocity centimeters per second									
Table (1)	Run no. (2)	Discharge, Q cubic centimeters per second (3)	Width of flume, B centimeters (4)	Mean water depth, D centimeters (5)	Water surface slope, S (6)	Water temperature degrees centigrade (7)	Mean V_m (8)	Bottom V_b (9)	Hydraulic radius of bed, r_b centimeters (10)	Friction velocity, V^* centimeters per second (11)	Reynolds Number, R (12)	Manning's n of bed, n_b (1) (13)	Unit discharge, q_b cubic centimeters per second per centimeter (14)	Rate of bed movement, $G^{(2)}$ grams per second per centimeter (15)	Duration of run minutes (16)	Bed condition (17)
							SAND I									
II	1		60.96	7.55	0.00113	22.2	40.2			2.89	31,948	0.0150	304	0.02903		Smooth
"	2		"	9.25	0.00112	22.2	44.0			3.19	42,842	0.0155	408	0.06000		"
"	3	No Observations	"	9.65	0.00113	22.2	49.4	No Observations		3.27	50,180	0.0143	475	0.06833	No Observations	Small Riffles
"	4		"	10.50	0.00112	22.8	55.7			3.40	62,551	0.0134	586	0.09667		" "
"	5		"	5.25	0.00167	20.5	34.0			2.93	18,030	0.0168	179	0.02283		Smooth
"	6		"	7.00	0.00167	20.5	42.3			3.39	29,909	0.0164	297	0.07800		Small Riffles
"	7		"	8.55	0.00165	19.4	44.4			3.72	37,291	0.0177	380	0.09467		Moderate "
"	8		"	9.90	0.00165	19.4	54.1			4.00	52,612	0.0161	537	0.16417		Riffles
"	9		"	2.05	0.00332	18.9	26.3			2.58	5,224	0.0164	54	0.03167		Smooth
"	10		"	2.90	0.00331	18.9	30.4			3.07	8,543	0.0179	88	0.06517		Small Riffles
"	11		"	3.60	0.00333	19.4	37.9			3.43	13,403	0.0167	137	0.10667		Moderate "
"	12		"	4.60	0.00333	18.9	45.4			3.88	20,236	0.0164	209	0.15633		Riffles
							SAND II									
II	13		60.96	7.55	0.00111	22.8	37.0			2.87	29,877	0.0161	278	0.02667		Smooth
"	14		"	7.85	0.00112	22.8	40.2			2.94	33,751	0.0153	315	0.04283		"
"	15		"	8.30	0.00113	23.3	43.8			3.03	39,302	0.0146	364	0.05333		Moderate Riffles
"	16	No Observations	"	9.75	0.00112	23.3	56.2	No Observations		3.27	59,238	0.0126	550	0.09583	No Observations	" "
"	17		"	9.90	0.00112	22.8	56.7			3.30	60,035	0.0127	560	0.10500		Riffles
"	18		"	4.45	0.00168	20.0	36.3			2.71	16,154	0.0142	161	0.01833		Smooth
"	19		"	6.20	0.00165	21.1	43.0			3.17	27,344	0.0148	266	0.06917		Small Riffles
"	20		"	6.75	0.00167	21.6	47.7			3.32	33,400	0.0142	322	0.10800		Moderate "
"	21		"	7.30	0.00166	21.6	50.2			3.45	38,015	0.0142	366	0.12900		Excessive "
"	22		"	8.10	0.00167	21.6	55.8			3.64	46,886	0.0137	452	0.16167		" "
"	23		"	2.65	0.00333	20.5	28.2			2.94	7,548	0.0182	75	0.06000		Smooth
"	24		"	2.76	0.00332	20.5	28.4			3.00	7,918	0.0186	78	0.08900		Small Riffles
"	25		"	3.90	0.00331	20.5	38.4			3.56	15,127	0.0173	149	0.15800		Riffles
"	26		"	4.70	0.00332	20.0	39.4			3.91	18,518	0.0190	185	0.14433		Excessive Riffles

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 31
U. S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS
SAND I

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G(2) grams per second per centimeter	Duration of run minutes	Bed condition
Table	Run no.						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
								SAND I								
11	12	8,127	73.6	3.44	0.0010	27.0	32.08	No Observations	3.16	1.76	11,889	0.0098	101.4	.00083	61	Smooth
〃	13	8,722	〃	3.60	〃	〃	32.90		3.28	1.79	12,676	0.0098	107.9	.00207	45	〃
〃	14	9,854	〃	3.87	〃	〃	34.58		3.51	1.86	14,251	0.0099	121.4	.00537	22	〃
〃	15	11,100	〃	4.27	〃	〃	35.30		3.85	1.94	15,962	0.0102	136.0	.00744	20	〃
〃	16	12,318	〃	4.75	〃	〃	35.22		4.30	2.05	17,765	0.0111	151.4	.00868	15	〃
〃	17	13,875	〃	5.06	〃	〃	37.24		4.53	2.11	19,797	0.0108	168.7	.01364	14	〃
〃	18	15,121	〃	5.49	〃	〃	37.40		4.91	2.19	21,554	0.0114	183.6	.01819	15	〃
〃	19	16,849	〃	5.70	〃	〃	40.14		5.03	2.22	23,679	0.0107	201.9	.02315	12	〃
〃	20	18,434	〃	6.28	〃	〃	39.86		5.55	2.33	25,953	0.0115	221.2	.02274	12	Local Riffles
〃	21	20,388	〃	6.52	〃	〃	42.46		5.69	2.36	28,359	0.0110	241.6	.03597	12	〃
〃	22	21,577	〃	6.92	〃	〃	42.34		6.04	2.43	30,006	0.0115	255.7	.03390	11	〃
〃	23	23,361	〃	7.32	〃	〃	43.34		6.36	2.50	32,327	0.0116	275.6	.03555	10	〃
〃	24	26,476	〃	7.68	〃	〃	46.81		6.54	2.53	35,937	0.0110	306.1	.05539	10	General Riffles
〃	25	28,317	〃	8.41	〃	〃	45.72		7.21	2.66	38,690	0.0120	329.6	.04093	12	〃
〃	26	29,733	〃	8.87	〃	〃	45.52		7.61	2.73	40,679	0.0125	346.4	.04919	10	〃
〃	27	31,573	〃	9.20	〃	〃	46.60		7.85	2.77	42,944	0.0124	365.8	.04713	10	〃
〃	28	32,848	〃	9.45	〃	〃	47.20		8.03	2.81	44,493	0.0125	379.0	.05663	10	〃
〃	29	35,679	〃	9.81	〃	〃	49.39		8.24	2.84	47,777	0.0121	407.0	.08309	10	〃
12	6	3,794	〃	1.89	0.0015	〃	27.26		1.80	1.63	5,753	0.0098	49.1	.00041	60	Smooth
〃	7	4,786	〃	2.16	〃	〃	30.09		2.05	1.74	7,223	0.0097	61.7	.00207	42	〃
〃	8	6,145	〃	2.59	〃	〃	32.22		2.43	1.89	9,198	0.0102	78.3	.00661	20	〃
〃	9	6,824	〃	2.74	〃	〃	33.82		2.56	1.94	10,175	0.0101	86.6	.00785	25	〃
〃	10	7,561	〃	3.02	〃	〃	34.00		2.81	2.03	11,226	0.0105	95.5	.00868	18	〃
〃	11	8,891	〃	3.29	〃	〃	36.70		3.05	2.12	13,116	0.0103	111.9	.01447	21	Local Riffles
〃	12	9,571	〃	3.60	〃	〃	36.10		3.33	2.21	14,115	0.0112	120.2	.01612	20	〃
〃	13	10,336	〃	3.81	〃	〃	36.84		3.52	2.28	15,235	0.0114	129.7	.01571	17	〃
〃	14	11,044	〃	4.05	〃	〃	37.03		3.75	2.35	16,281	0.0118	138.9	.01860	20	〃
〃	15	11,780	〃	4.18	〃	〃	38.27		3.84	2.38	17,250	0.0116	147.0	.02191	20	〃
〃	16	13,082	〃	4.48	〃	〃	39.65		4.10	2.46	19,078	0.0117	162.6	.03018	17	〃
〃	17	13,875	〃	4.66	〃	〃	40.43		4.26	2.50	20,206	0.0117	172.2	.03969	17	〃
〃	18	14,895	〃	4.85	〃	〃	41.71		4.40	2.54	21,540	0.0116	183.5	.04713	16	〃
〃	19	15,914	〃	5.03	〃	〃	42.96		4.55	2.59	22,930	0.0115	195.5	.05043	14	〃
〃	20	17,188	〃	5.33	〃	〃	43.79		4.81	2.66	24,704	0.0117	210.6	.05581	16	〃
〃	21	18,349	〃	5.58	〃	〃	44.65		5.01	2.71	26,244	0.0118	223.7	.05250	14	General Riffles
〃	22	19,284	〃	5.79	〃	〃	45.23		5.19	2.76	27,539	0.0119	234.7	.05663	16	〃
〃	23	21,153	〃	6.22	〃	〃	46.18		5.55	2.86	30,084	0.0122	256.3	.06408	15	〃
〃	24	22,172	〃	6.43	〃	〃	46.82		5.73	2.90	31,472	0.0123	268.3	.06986	12	〃
〃	25	23,050	〃	6.61	〃	〃	47.35		5.88	2.94	32,692	0.0124	278.4	.07606	13	〃
〃	26	23,645	〃	6.64	〃	〃	48.36		5.89	2.94	33,407	0.0122	284.8	.08947	12	〃
〃	27	24,919	〃	6.92	〃	〃	48.90		6.12	3.00	35,109	0.0123	299.3	.09797	12	〃
〃	28	25,542	〃	7.25	〃	〃	47.84		6.43	3.08	36,128	0.0130	307.6	.06490	12	〃
〃	29	30,186	〃	7.83	〃	〃	52.35		6.82	3.02	41,894	0.0123	357.0	.11823	10	〃
〃	30	31,290	〃	8.23	〃	〃	51.63		7.19	3.25	43,590	0.0130	371.2	.10624	10	〃
13	5	3,285	〃	1.62	0.0020	〃	27.54		1.55	1.74	5,014	0.0100	42.7	.00041	110	Smooth
〃	6	3,540	〃	1.92	〃	〃	25.04		1.83	1.89	5,383	0.0102	45.8	.00289	64	〃
〃	7	5,210	〃	2.13	〃	〃	33.22		2.02	1.99	7,879	0.0100	67.1	.00868	30	〃
〃	8	6,286	〃	2.47	〃	〃	34.56		2.33	2.14	9,458	0.0106	80.5	.01158	30	〃
〃	9	7,306	〃	2.65	〃	〃	37.44		2.49	2.21	10,929	0.0102	93.2	.01984	30	〃
〃	10	8,410	〃	3.02	〃	〃	37.82		2.83	2.36	12,542	0.0110	107.0	.02150	32	Local Riffles
〃	11	9,401	〃	3.29	〃	〃	38.80		3.08	2.46	14,005	0.0113	119.5	.02150	35	〃
〃	12	10,279	〃	3.54	〃	〃	39.43		3.29	2.54	15,248	0.0116	129.7	.04010	24	〃
〃	13	11,327	〃	3.78	〃	〃	40.69		3.51	2.62	16,763	0.0119	142.8	.05167	29	〃
〃	14	11,836	〃	3.99	〃	〃	40.28		3.72	2.70	17,565	0.0124	149.8	.03845	29	〃
〃	15	14,300	〃	4.30	〃	〃	45.16		3.94	2.78	20,905	0.0115	177.9	.07028	29	General Riffles
〃	16	16,226	〃	4.82	〃	〃	45.71		4.41	2.94	23,662	0.0122	201.6	.06780	20	〃
〃	17	18,349	〃	5.43	〃	〃	45.89		4.97	3.12	26,743	0.0132	228.1	.06408	26	〃
〃	18	20,813	〃	5.73	〃	〃	49.32		5.19	3.19	30,030	0.0126	256.0	.09260	23	〃
〃	19	22,229	〃	6.04	〃	〃	49.98		5.45	3.27	31,987	0.0129	272.4	.10624	17	〃
〃	20	24,352	〃	6.37	〃	〃	51.91		5.72	3.35	34,857	0.0128	296.9	.13394	10	〃
〃	21	27,099	〃	6.71	〃	〃	54.84		5.96	3.42	38,393	0.0125	326.8	.13559	13	〃

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 31 (CONTINUED)
U. S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS
SANDS 2 AND 3

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
Table	Run no.						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND 2																
14	9	7,561	73.6	3.63	0.0010	27.0	28.29	No Observations	3.37	1.82	11,203	0.0117	95.3	0.00248	45	Smooth
"	10	8,920	"	3.99	"	"	30.36		3.69	1.90	13,142	0.0116	112.3	0.00455	40	"
"	11	11,044	"	4.60	"	"	32.60		4.21	2.03	16,093	0.0117	137.2	0.01116	25	"
"	12	13,309	"	5.24	"	"	34.49		4.76	2.16	19,249	0.0121	164.2	0.01654	26	"
"	13	15,857	"	5.88	"	"	36.62		5.28	2.28	22,703	0.0122	193.4	0.02274	33	General Riffles
"	14	21,039	"	7.22	"	"	39.57		6.39	2.50	29,687	0.0128	252.9	0.02894	28	"
"	15	23,616	"	7.77	"	"	41.27		6.82	2.59	33,055	0.0128	281.5	0.03307	25	"
"	16	25,485	"	8.23	"	"	42.05		7.19	2.66	35,501	0.0130	302.3	0.04010	20	"
"	17	28,175	"	8.72	"	"	43.88		7.54	2.72	38,853	0.0129	330.9	0.04010	20	"
"	18	30,780	"	9.27	"	"	45.09		7.97	2.80	42,185	0.0130	359.4	0.06242	20	"
"	19	33,414	"	9.78	"	"	46.40		8.36	2.86	45,534	0.0130	387.9	0.06532	15	"
"	20	36,812	"	10.70	"	"	46.72		9.13	2.99	50,043	0.0137	426.6	0.08268	12	"
"	21	40,493	"	11.67	"	"	47.12		9.92	3.12	54,868	0.0143	467.4	0.11740	10	"
15	13	6,428	73.6	2.96	0.0015	27.0	29.49		2.80	2.03	9,674	0.0121	82.6	0.00496	21	Smooth
"	14	8,410	"	3.47	"	"	32.91		3.25	2.19	12,561	0.0120	107.0	0.01819	8	"
"	15	11,667	"	4.27	"	"	37.10		3.94	2.41	17,148	0.0121	146.2	0.02728	8	Local Riffles
"	16	13,479	"	4.79	"	"	38.21		4.40	2.54	19,737	0.0127	168.1	0.03142	19	General Riffles
"	17	21,521	"	6.64	"	"	44.01		5.99	2.97	30,921	0.0135	263.6	0.05787	10	"
"	18	23,673	"	7.13	"	"	45.09		6.40	3.07	33,860	0.0137	288.6	0.04547	15	"
"	19	26,136	"	7.65	"	"	46.39		6.83	3.17	37,194	0.0140	316.8	0.07937	9	"
"	20	29,450	"	8.26	"	"	48.42		7.31	3.28	41,538	0.0140	354.0	0.13063	10	"
"	21	34,716	"	9.39	"	"	50.21		8.25	3.48	48,607	0.0146	414.2	0.12484	10	"
"	22	39,360	"	10.21	"	"	52.35		8.90	3.62	54,685	0.0147	465.9	0.10996	10	"
"	23	41,343	"	11.00	"	"	51.04		9.64	3.77	57,755	0.0160	492.0	0.07606	10	"
"	24	51,423	"	12.59	"	"	55.46		10.82	3.99	70,432	0.0159	600.1	0.27408	7	"
16	9	4,248	73.6	2.19	0.0020	27.0	26.34		2.12	2.04	6,539	0.0131	55.8	0.00041	31	Smooth
"	10	5,295	"	2.50	"	"	28.76		2.40	2.17	8,088	0.0130	69.0	0.01530	10	"
"	11	6,824	"	2.80	"	"	33.10		2.66	2.28	10,326	0.0120	88.0	0.01984	8	Local Riffles
"	12	8,127	"	3.14	"	"	35.15		2.96	2.41	12,224	0.0122	104.0	0.02687	7	"
"	13	10,732	"	3.90	"	"	37.37		3.66	2.68	16,045	0.0131	136.8	0.01943	8	General Riffles
"	14	12,912	"	4.45	"	"	39.40		4.15	2.85	19,196	0.0137	163.5	0.04175	22	"
"	15	15,574	"	5.03	"	"	42.05		4.65	3.02	22,970	0.0138	195.5	0.05787	10	"
"	16	18,689	"	5.88	"	"	43.16		5.43	3.26	27,482	0.0148	234.4	0.08185	10	"
"	17	21,238	"	6.40	"	"	45.06		5.87	3.39	31,061	0.0150	264.5	0.11327	10	"
"	18	23,220	"	6.80	"	"	46.37		6.21	3.49	33,792	0.0150	288.0	0.12443	8	"
"	19	26,165	"	7.16	"	"	49.62		6.48	3.56	37,739	0.0145	321.5	0.11079	7	"
"	20	28,260	"	7.56	"	"	50.76		6.82	3.66	40,620	0.0148	346.2	0.10500	8	"
"	21	30,582	"	8.05	"	"	51.59		7.24	3.77	43,815	0.0151	373.5	0.21620	7	"
"	23	35,056	"	8.75	"	"	54.41		7.79	3.91	49,735	0.0149	423.9	0.19595	5	"
"	24	36,755	"	9.20	"	"	54.25		8.20	4.01	52,206	0.0156	444.9	0.14799	5	"
SAND 3																
17	15	5267	70.5	2.90	0.0010	17.5	25.76	29.57	2.72	1.63	6,541	0.0115	70.1	0.00021	60	Smooth
"	16	5,862	"	3.05	"	16.0	27.26	32.00	2.84	1.67	6,938	0.0107	77.4	0.00012	79	"
"	17	6,654	"	3.29	"	16.2	28.69	31.39	3.05	1.73	7,878	0.0107	87.5	0.00083	56	"
"	18	7,362	"	3.57	"	16.4	29.25	32.00	3.30	1.80	8,746	0.0111	96.5	0.00083	60	"
"	19	8,467	"	3.84	"	16.4	31.28	34.75	3.53	1.86	10,020	0.0111	110.4	0.00207	64	"
"	20	9,373	"	4.15	"	16.5	32.04	35.05	3.79	1.93	11,045	0.0114	121.4	0.00413	50	"
"	21	11,298	"	4.69	"	16.8	34.17	36.27	4.26	2.04	13,339	0.0115	145.6	0.00827	36	Local Riffles
"	23	16,622	"	8.50	"	17.0	27.74	22.25	7.92	2.79	20,220	0.0212	219.7	0.00124	64	General Riffles
"	24	20,643	"	9.85	"	17.0	29.73	25.30	9.07	2.98	24,832	0.0214	269.7	0.00455	54	"
"	25	24,636	"	10.24	"	16.8	34.13	28.96	9.26	3.01	28,985	0.0190	316.0	0.01736	69	"
"	26	29,733	"	11.28	"	17.0	37.39	32.31	10.06	3.14	34,629	0.0185	376.1	0.02852	61	"
"	27	35,679	"	12.44	"	17.0	40.68	36.27	10.91	3.27	40,852	0.0180	443.8	0.05333	60	"
"	28	41,059	"	13.35	"	17.0	43.63	31.09	11.50	3.36	46,189	0.0171	501.7	0.04961	45	"
"	29	48,733	"	14.51	"	17.0	47.64	28.04	12.21	3.46	53,562	0.0163	581.7	0.07565	50	"
"	30	55,926	"	16.79	"	17.0	47.25	37.49	14.16	3.73	61,625	0.0182	669.1	0.12608	40	"
"	31	64,194	"	18.99	"	17.0	47.95	44.50	15.95	3.95	70,437	0.0194	763.8	0.13187	30	"
18	23	4,984	70.5	2.65	0.0015	19.0	26.68	28.35	2.52	1.93	6,532	0.0126	67.2	0.00041	61	Smooth
"	24	5,522	"	2.80	"	19.2	27.97	28.65	2.66	1.98	7,259	0.0123	74.4	0.00124	60	"
"	25	5,947	"	3.02	"	19.4	27.93	33.22	2.86	2.05	7,844	0.0129	79.9	0.00496	40	"
"	26	6,796	"	3.20	"	19.5	30.12	33.53	3.01	2.10	8,926	0.0124	90.7	0.00703	30	"
"	27	7,079	"	3.32	"	19.0	30.24	33.53	3.13	2.15	9,172	0.0127	94.7	0.00661	30	"
"	28	7,787	"	3.54	"	19.0	31.20	33.83	3.32	2.21	10,044	0.0129	103.6	0.01075	30	Local Riffles

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 31 (CONTINUED)
U. S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS
SANDS 3 AND 4

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
Table	Run no.						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND 3 (CONTINUED)																
18	29	9,769	70.5	5.91	0.0015	19.0	23.45	-	5.68	2.89	12,908	0.0244	133.2	0.00207	61	General Riffles
"	30	12,743	"	6.92	"	19.0	26.21	23.77	6.59	2.87	16,696	0.0241	172.7	0.00248	73	"
"	31	16,424	"	7.59	"	18.5	30.69	25.30	7.14	3.24	21,007	0.0217	219.1	0.01364	62	"
"	32	20,388	"	7.92	"	18.5	36.51	26.82	7.30	3.28	25,564	0.0185	266.5	0.02894	77	Large Riffles
"	33	24,352	"	8.56	"	19.0	40.35	31.39	7.79	3.39	30,468	0.0176	314.3	0.03886	63	"
"	34	29,166	"	9.63	"	18.5	42.96	32.61	8.67	3.57	35,707	0.0177	372.5	0.08061	70	"
"	35	34,688	"	11.83	"	18.5	41.59	28.65	10.69	3.97	42,611	0.0209	444.6	0.09177	58	"
"	36	41,767	"	13.44	"	18.5	44.08	32.61	12.03	4.21	50,859	0.0213	530.3	0.17280	46	Sand Waves
19	20	3,143	70.5	1.71	0.0020	16.7	26.07	-	1.64	1.79	3,915	0.0110	42.8	0.00012	71	Smooth
"	21	3,681	"	1.86	"	16.7	28.07	25.30	1.78	1.87	4,567	0.0109	50.0	0.00041	63	"
"	22	4,248	"	2.01	"	16.8	29.98	25.60	1.92	1.94	5,273	0.0107	57.6	0.00124	46	"
"	23	5,239	"	2.38	"	16.8	31.22	28.35	2.26	2.11	6,470	0.0114	70.6	0.00992	40	"
"	24	5,833	"	2.68	"	16.2	30.87	32.61	2.55	2.24	7,095	0.0126	78.8	0.01612	38	Local Riffles
"	25	7,108	"	3.87	"	16.2	26.05	28.35	3.73	2.70	8,742	0.0193	97.2	0.01075	60	General Riffles
"	26	7,957	"	4.33	"	16.0	26.07	26.21	4.16	2.86	9,736	0.0205	108.5	0.01116	30	"
"	27	9,005	"	4.75	"	16.1	26.89	26.21	4.57	2.99	11,041	0.0213	122.9	0.00868	31	"
"	28	9,203	"	4.94	"	10.8	26.42	26.21	4.75	3.05	9,796	0.0221	125.5	0.01075	30	"
"	29	11,610	"	5.43	"	16.1	30.33	20.73	5.17	3.18	14,090	0.0204	156.8	0.00455	30	"
"	30	17,868	"	6.55	"	16.0	38.69	29.57	6.11	3.46	21,184	0.0179	236.4	0.04961	40	"
"	31	21,804	"	6.68	"	15.8	46.30	37.49	6.08	3.45	25,114	0.0149	281.5	0.07689	30	"
"	32	26,335	"	7.04	"	16.0	53.06	38.40	6.27	3.51	29,837	0.0133	332.7	0.15874	51	"
"	33	31,998	"	8.47	"	16.0	53.59	37.49	7.53	3.84	36,186	0.0149	403.5	0.18933	30	"
"	34	38,256	"	10.03	"	16.0	54.10	-	8.89	4.18	43,125	0.0164	480.9	0.20752	30	"
SAND 4																
20	19	6,315	70.5	3.23	0.0010	16.9	27.73	26.82	3.00	1.72	7,651	0.0110	83.2	0.00041	47	Smooth
"	20	7,079	"	3.44	"	16.6	29.19	34.75	3.18	1.77	8,459	0.0109	92.8	0.00165	60	"
"	21	8,976	"	4.02	"	16.5	31.67	35.97	3.68	1.90	10,584	0.0110	116.5	0.00744	50	"
"	22	10,760	"	4.48	"	16.5	34.07	35.97	4.05	1.99	12,547	0.0109	138.0	0.01034	30	"
"	23	12,601	"	5.09	"	16.5	35.11	37.49	4.58	2.12	14,622	0.0116	160.8	0.01116	20	"
"	24	14,611	"	7.77	"	16.5	26.67	28.65	7.25	2.67	17,580	0.0205	193.4	0.00372	60	General Riffles
"	25	16,141	"	8.44	"	16.9	27.13	25.91	7.87	2.78	19,617	0.0214	213.5	0.00331	60	"
"	26	17,981	"	9.33	"	17.0	27.34	26.82	8.68	2.92	21,854	0.0226	237.3	0.00289	60	"
"	27	22,115	"	10.70	"	17.0	29.32	27.74	9.88	3.11	26,680	0.0231	289.7	0.00455	60	"
"	28	27,467	"	11.83	"	17.0	32.93	29.87	10.75	3.25	32,596	0.0217	354.0	0.00868	47	"
"	29	33,980	"	12.92	"	17.5	37.31	34.75	11.51	3.36	40,046	0.0201	429.4	0.01819	43	"
"	30	42,051	"	13.96	"	17.5	42.73	40.23	12.09	3.44	48,171	0.0181	516.6	0.03845	30	"
"	31	47,572	"	14.84	"	17.8	45.47	43.28	12.65	3.52	54,157	0.0175	575.2	0.04506	30	"
"	32	55,501	"	16.06	"	17.9	49.02	-	13.40	3.62	61,950	0.0169	656.9	0.09177	30	"
21	17	3,681	70.5	2.01	0.0015	17.3	25.98	37.49	1.92	1.68	4,624	0.0107	49.9	0.00207	60	Smooth
"	18	5,069	"	2.47	"	17.2	29.11	35.97	2.33	1.85	6,278	0.0108	67.8	0.00207	30	"
"	19	5,805	"	2.68	"	17.2	30.72	38.71	2.52	1.93	7,171	0.0108	77.4	0.00413	60	"
"	20	7,164	"	2.99	"	17.2	33.98	41.76	2.78	2.02	8,737	0.0104	94.5	0.00868	60	"
"	21	7,929	"	3.41	"	17.1	32.98	44.81	3.18	2.16	9,690	0.0117	104.9	0.01654	30	Local Riffles
"	22	9,061	"	5.85	"	17.0	21.97	22.25	5.64	2.88	11,408	0.0260	123.9	0.00041	60	General Riffles
"	23	10,760	"	6.61	"	17.0	23.09	22.86	6.35	3.06	13,505	0.0267	146.6	0.00124	50	"
"	24	12,176	"	7.10	"	17.0	24.33	22.86	6.80	3.16	15,228	0.0265	165.4	0.00372	45	"
"	25	13,790	"	7.35	"	16.8	26.61	24.38	6.98	3.20	17,047	0.0246	185.7	0.00951	50	"
"	26	16,424	"	7.83	"	16.8	29.75	28.65	7.38	3.29	20,140	0.0170	219.6	0.01323	48	"
"	27	19,255	"	8.60	"	16.0	31.76	32.00	8.05	3.44	22,930	0.0228	255.7	0.01902	30	"
"	28	23,361	"	9.63	"	16.0	34.41	33.22	8.94	3.63	27,590	0.0225	307.6	0.02191	30	"
"	29	28,317	"	10.39	"	16.1	38.66	37.49	9.50	3.74	33,012	0.0209	367.3	0.04299	30	"
"	30	35,113	"	10.94	"	16.2	45.53	45.11	9.74	3.79	39,943	0.0179	443.5	0.12402	30	Large Riffles
"	31	41,258	"	11.43	"	16.4	51.20	48.46	9.94	3.82	46,182	0.0162	508.9	0.12691	30	"
22	19	4,106	70.5	2.01	0.0020	15.3	28.97	-	1.92	1.94	4,882	0.0111	55.6	0.00083	60	Smooth
"	20	4,814	"	2.23	"	15.3	30.62	-	2.12	2.04	5,684	0.0111	64.9	0.00537	53	"
"	21	5,267	"	2.38	"	15.3	31.39	33.53	2.26	2.11	6,215	0.0114	70.9	0.00868	35	"
"	22	6,400	"	2.71	"	15.3	33.50	37.49	2.56	2.24	7,525	0.0116	85.8	0.01778	20	Local Riffles
"	24	9,061	"	5.39	"	15.3	23.84	18.59	5.22	3.20	10,896	0.0263	124.4	0.00331	60	General Riffles
"	25	10,194	"	5.91	"	15.4	24.47	22.86	5.71	3.35	12,358	0.0272	139.7	0.01778	35	"
"	26	13,224	"	6.64	"	15.6	28.25	21.95	6.36	3.53	15,945	0.0252	179.7	0.02067	30	"
"	27	16,849	"	7.35	"	15.6	32.52	24.69	6.96	3.69	20,072	0.0232	226.3	0.03183	30	"
"	28	20,303	"	8.02	"	15.6	35.91	27.13	7.53	3.84	23,980	0.0222	270.4	0.05622	30	"
"	29	24,069	"	8.75	"	15.6	39.02	28.35	8.14	4.00	28,186	0.0216	317.6	0.05911	30	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 31 (CONTINUED)
U. S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS
SANDS 4, 5 AND 6

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, $G^{(2)}$ grams per second per centimeter	Duration of run minutes	Bed condition
Table	Run no.						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND 4 (CONTINUED)																
22	30	29,761	70.5	9.11	0.0020	15.7	46.34	32.00	8.29	4.03	34,170	0.0182	384.2	0.20504	31	General Riffles
"	31	35,396	"	9.30	"	16.0	53.99	36.27	8.24	4.02	39,880	0.0156	444.9	0.24307	20	"
"	32	41,626	"	10.49	"	16.0	56.29	53.04	9.22	4.25	46,547	0.0162	519.0	0.33691	16	"
SAND 5																
23	22	7,900	70.5	3.66	0.0010	15.9	30.62	37.49	3.36	1.82	9,216	0.0108	102.9	0.00289	45	Smooth
"	23	9,033	"	3.99	"	16.0	32.11	37.49	3.65	1.89	10,497	0.0109	117.2	0.00455	40	Local Riffles
"	29	20,671	"	10.27	"	16.0	28.55	26.52	9.51	3.05	24,351	0.0230	271.5	0.00041	60	General Riffles
"	30	23,503	"	11.06	"	16.1	30.14	27.74	10.18	3.16	27,567	0.0229	306.8	0.00207	30	"
"	31	28,572	"	12.28	"	16.1	33.00	30.18	11.17	3.31	33,104	0.0223	368.6	0.00827	60	"
"	32	34,688	"	13.59	"	16.2	36.20	33.53	12.16	3.45	39,650	0.0214	440.2	0.01488	30	"
"	33	39,644	"	14.75	"	16.2	38.12	31.39	13.08	3.58	44,906	0.0214	498.6	0.02356	25	"
"	34	44,431	"	15.91	"	16.0	39.61	39.01	13.79	3.68	48,996	0.0199	546.2	0.04754	30	"
"	35	51,452	"	16.76	"	16.0	43.55	42.67	14.44	3.76	56,381	0.0199	628.9	0.05539	30	"
"	36	58,871	"	17.04	"	16.0	49.01	44.50	14.22	3.73	62,487	0.0175	696.9	0.12484	20	"
24	15	3,993	70.5	2.16	0.0015	15.8	26.22	–	2.06	1.74	4,823	0.0111	54.0	0.00124	60	Smooth
"	16	5,040	"	2.44	"	15.8	29.30	–	2.30	1.84	6,020	0.0107	67.4	0.00496	30	"
"	17	6,173	"	2.80	"	15.8	31.27	–	2.63	1.97	7,343	0.0110	82.2	0.00827	30	"
"	18	7,023	"	3.08	"	15.8	32.34	–	2.88	2.06	8,307	0.0113	93.1	0.01158	30	Local Riffles
"	22	15,178	"	7.92	"	15.5	27.18	26.52	7.53	3.33	18,118	0.0255	204.7	0.00661	60	General Riffles
"	23	18,010	"	8.72	"	15.5	29.30	33.53	8.23	3.48	21,351	0.0250	241.1	0.01447	45	"
"	24	22,653	"	9.85	"	15.5	32.62	33.53	9.19	3.68	26,553	0.0242	299.8	0.02232	30	"
"	25	27,467	"	10.79	"	15.5	36.11	34.44	9.96	3.83	31,869	0.0232	359.7	0.03597	30	"
"	26	33,272	"	11.83	"	15.5	39.89	33.53	10.77	3.98	38,039	0.0220	429.6	0.03803	30	"
"	27	39,360	"	12.68	"	15.6	44.03	36.27	11.35	4.09	44,346	0.0205	499.7	0.06904	30	"
"	28	46,723	"	13.59	"	15.8	48.77	42.98	11.95	4.19	52,040	0.0193	582.8	0.10872	30	"
25	17	3,625	70.5	1.86	0.0020	15.6	27.64	39.01	1.78	1.87	4,373	0.0110	49.2	0.00041	60	Smooth
"	18	4,219	"	2.01	"	15.6	29.77	41.15	1.92	1.94	5,072	0.0109	57.2	0.00124	70	"
"	19	4,870	"	2.26	"	15.8	30.57	44.20	2.15	2.05	5,857	0.0112	65.7	0.00413	60	"
"	21	9,769	"	5.76	"	16.0	24.06	25.91	5.57	3.31	12,011	0.0271	134.0	0.00165	58	General Riffles
"	22	12,799	"	6.77	"	16.0	26.82	32.00	6.50	3.57	15,630	0.0269	174.3	0.00951	66	"
"	23	15,433	"	7.62	"	16.1	28.73	39.01	7.28	3.78	18,797	0.0270	209.2	0.01571	30	"
"	24	19,255	"	8.26	"	16.2	33.07	32.31	7.81	3.91	23,265	0.0246	258.3	0.03472	36	"
"	25	23,220	"	9.02	"	16.3	36.51	44.50	8.45	4.07	27,901	0.0236	308.5	0.04299	30	"
"	26	28,034	"	9.88	"	16.4	40.25	46.02	9.16	4.24	33,464	0.0226	368.7	0.06325	30	"
"	27	33,669	"	10.79	"	16.5	44.26	46.02	9.89	4.40	39,774	0.0217	437.7	0.11327	30	"
"	28	39,927	"	11.40	"	16.6	49.68	–	10.26	4.49	46,436	0.0197	509.7	0.13476	20	"
SAND 6																
26	5	11,525	73.6	7.10	0.0010	18.0	22.04	No Observations	6.76	2.57	14,104	0.0239	149.0	0.00124	60	Local Riffles
"	6	14,272	"	7.47	"	"	25.94		7.01	2.62	17,203	0.0207	181.8	0.00248	60	General Riffles
"	7	15,971	"	8.56	"	"	25.34		8.06	2.81	19,327	0.0233	204.2	0.00083	60	"
"	8	18,491	"	9.42	"	"	26.66		8.82	2.94	22,256	0.0236	235.1	0.00248	63	"
"	9	20,898	"	10.00	"	"	28.38		9.30	3.02	24,975	0.0229	263.9	0.00372	36	"
"	10	23,588	"	10.79	"	"	29.69		9.98	3.13	28,022	0.0228	296.3	0.00207	44	"
"	11	26,533	"	11.46	"	"	31.44		10.53	3.21	31,324	0.0224	331.1	0.00331	30	"
"	12	29,619	"	11.92	"	"	33.74		10.83	3.26	34,580	0.0212	365.4	0.00620	30	"
"	13	31,856	"	12.44	"	"	34.77		11.26	3.32	37,027	0.0212	391.5	0.00661	30	"
"	14	34,462	"	13.11	"	"	35.70		11.82	3.40	39,912	0.0214	422.0	0.00868	30	"
"	15	37,095	"	13.53	"	"	37.23		12.11	3.45	42,665	0.0208	450.9	0.01075	30	"
"	16	38,822	"	14.39	"	"	36.64		12.92	3.56	44,776	0.0221	473.4	0.01571	30	"
"	17	41,937	"	14.97	"	"	38.04		13.34	3.62	48,002	0.0216	507.5	0.01530	30	"
"	18	44,316	"	16.00	"	"	37.61		14.30	3.74	50,896	0.0231	537.8	0.01406	30	"
27	8	9,260	73.6	5.73	0.0015	20.0	21.95		5.53	2.85	12,136	0.0256	121.4	0.00083	59	General Riffles
"	9	10,024	"	6.22	"	"	21.88		6.00	2.97	13,132	0.0270	131.3	0.00083	47	"
"	10	11,893	"	6.86	"	"	23.54		6.59	3.11	15,520	0.0270	155.1	0.00041	75	"
"	11	13,224	"	7.10	"	20.9	25.29		6.79	3.16	17,182	0.0255	171.7	0.00207	51	"
"	12	15,999	"	7.89	"	20.0	27.54		7.51	3.32	21,096	0.0252	206.8	0.00207	65	"
"	13	19,057	"	8.72	"	"	29.68		8.24	3.48	24,961	0.0248	244.6	0.00620	40	"
"	14	22,738	"	9.48	"	"	32.57		8.88	3.61	29,499	0.0237	289.2	0.00868	44	"
"	15	26,618	"	10.24	"	"	35.30		9.51	3.74	34,245	0.0228	335.7	0.01158	27	"
"	16	30,299	"	11.13	"	"	36.97		10.28	3.89	38,773	0.0231	380.1	0.01406	34	"
"	17	33,414	"	11.46	"	"	39.59		10.49	3.93	42,369	0.0218	415.3	0.02811	34	"
"	18	35,764	"	12.16	"	"	39.94		11.12	4.04	45,303	0.0224	444.1	0.02604	52	"
"	19	38,171	"	12.59	"	"	41.17		11.46	4.11	48,131	0.0222	471.8	0.03514	27	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 31 (CONTINUED)
U. S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS
SANDS 6 AND 7

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G(2) grams per second per centimeter	Duration of run minutes	Bed condition
Table (1)	Run no. (2)	(3)	(4)	(5)	(6)	(7)	Mean V_m (8)	Bottom V_b (9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND 6 (CONTINUED)																
27	20	39,644	73.6	12.98	0.0015	20.0	41.48		11.80	4.17	49,954	0.0225	489.5	0.03762	34	General Riffles
"	21	42,475	"	13.59	"	"	42.44		12.32	4.26	53,340	0.0227	522.9	0.02852	38	"
"	22	46,581	"	14.20	"	"	44.55		12.76	4.33	57,988	0.0220	568.5	0.04465	40	"
28	6	5,947	73.6	3.66	0.0020	23.0	22.07		3.55	2.64	8,434	0.0221	78.3	0.00331	30	General Riffles
"	7	7,872	"	4.54	"	"	23.55		4.40	2.94	11,144	0.0238	103.6	0.00289	39	"
"	8	9,571	"	5.33	"	"	24.38		5.16	3.18	13,527	0.0254	125.8	0.00331	36	"
"	9	11,893	"	6.31	"	"	25.59	No Observations	6.09	3.46	16,736	0.0270	155.8	0.00703	34	"
"	10	14,442	"	7.28	"	"	26.94		7.01	3.71	20,306	0.0283	188.8	0.00661	33	"
"	11	16,311	"	7.74	"	"	28.62		7.42	3.81	22,831	0.0276	212.4	0.00951	30	"
"	12	18,717	"	8.14	"	"	31.22		7.75	3.90	26,030	0.0262	242.0	0.01571	30	"
"	13	21,011	"	8.50	"	"	33.57		8.06	3.98	29,080	0.0249	270.6	0.01902	30	"
"	14	23,730	"	9.24	"	"	34.88		8.72	4.14	32,693	0.0253	304.2	0.02026	30	"
"	15	26,250	"	9.69	"	"	36.79		9.10	4.22	36,003	0.0246	334.8	0.02274	31	"
"	16	28,317	"	10.09	"	"	38.11		9.44	4.30	38,684	0.0243	359.8	0.03721	30	"
"	17	31,573	"	10.45	"	"	41.03		9.70	4.36	42,804	0.0230	398.0	0.03638	30	"
"	18	34,632	"	10.88	"	"	43.23		10.04	4.44	46,656	0.0223	434.0	0.05498	30	"
"	19	37,095	"	11.19	"	"	45.02		10.26	4.49	49,682	0.0217	461.9	0.07524	30	"
"	20	38,709	"	11.37	"	"	46.23		10.40	4.52	51,698	0.0215	480.8	0.06077	30	"
"	21	41,116	"	11.73	"	"	47.60		10.69	4.58	54,694	0.0212	508.8	0.08722	30	"
SAND 7																
29	8	5,833	73.6	2.90	0.0010	27.0	27.31		2.70	1.63	8,667	0.0104	73.7	0.00041	60	Smooth
"	10	7,136	"	3.38	"	"	28.67		3.14	1.75	10,573	0.0110	90.0	0.00248	18	"
"	14	10,279	"	6.80	"	"	20.52		6.51	2.53	15,672	0.0250	133.6	0.00041	85	General Riffles
"	15	11,327	"	7.28	"	"	21.13		6.96	2.61	17,266	0.0255	147.1	0.00083	85	"
"	16	11,780	"	7.56	"	"	21.16		7.22	2.66	17,919	0.0257	152.8	0.00124	75	"
"	17	13,394	"	8.60	"	"	21.15		8.21	2.84	20,383	0.0284	173.6	0.00083	75	"
"	18	16,707	"	9.30	"	"	24.40		8.78	2.93	25,139	0.0257	214.2	0.00207	65	"
"	19	19,029	"	10.18	"	"	25.38	–	9.58	3.06	28,547	0.0261	243.1	0.00331	30	"
"	20	21,379	"	10.85	"	"	26.76		10.15	3.15	31,889	0.0257	271.6	0.00331	32	"
"	21	24,126	"	11.46	"	"	28.59		10.65	3.23	35,738	0.0248	304.5	0.00496	31	"
"	22	26,816	"	12.10	"	"	30.10		11.17	3.31	39,476	0.0243	336.2	0.00703	28	"
30	14	3,681	73.6	1.77	0.0015	27.0	28.24		1.68	1.57	5,555	0.0090	47.4	0.00041	50	Local Riffles
"	15	3,710	"	3.35	"	"	15.04	No Observations	3.29	2.20	5,801	0.0266	49.5	0.00041	56	"
"	17	7,447	"	5.03	"	"	20.10		4.87	2.68	11,499	0.0257	97.9	0.00124	65	General Riffles
"	18	10,647	"	6.34	"	"	22.80		6.11	3.00	16,337	0.0263	139.3	0.00331	33	"
"	19	14,300	"	7.35	"	"	26.42		7.00	3.21	21,719	0.0248	184.9	0.00413	30	"
"	20	17,698	"	8.63	"	"	27.85		8.19	3.47	26,771	0.0261	228.1	0.00868	30	"
"	21	21,039	"	9.14	"	"	31.26		8.61	3.56	31,572	0.0243	269.1	0.01199	32	"
"	22	25,400	"	10.36	"	"	33.29		9.69	3.78	37,850	0.0246	322.6	0.01323	30	"
"	23	28,996	"	11.22	"	"	35.09		10.43	3.92	42,944	0.0245	366.0	0.01695	30	"
31	12	2,775	73.6	1.49	0.0020	27.0	25.29		1.44	1.68	4,280	0.0105	36.4	0.00331	8	Smooth
"	13	3,794	"	1.86	"	"	27.70		1.79	1.87	5,807	0.0110	49.6	0.00331	10	Local Riffles
"	15	5,267	"	3.75	"	"	19.07		3.66	2.68	8,201	0.0258	69.8	0.00041	38	General Riffles
"	16	6,570	"	4.54	"	"	19.65		4.44	2.95	10,229	0.0288	87.2	0.00083	53	"
"	17	8,070	"	5.18	"	"	21.16		5.04	3.14	12,527	0.0291	106.6	0.00248	25	"
"	18	9,345	"	5.76	"	"	22.03		5.60	3.31	14,477	0.0298	123.4	0.00124	40	"
"	19	12,516	"	6.58	"	"	25.83		6.35	3.53	19,257	0.0279	164.0	0.00827	38	"
"	20	15,801	"	7.41	"	"	28.96		7.09	3.73	24,110	0.0265	205.3	0.01323	34	"
"	21	19,142	"	8.53	"	"	30.47		8.14	4.00	29,125	0.0276	248.0	0.02232	25	"
"	22	23,163	"	8.99	"	"	34.99		8.49	4.08	34,850	0.0247	297.1	0.02687	24	"
"	23	26,986	"	9.42	"	"	38.90		8.79	4.15	40,146	0.0227	341.9	0.05829	17	"
"	24	32,451	"	10.55	"	"	41.77		9.78	4.38	47,937	0.0229	408.5	0.08557	15	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 31 (CONTINUED)
U. S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS
SANDS 8 AND 9

Author's references: Table (1)	Author's references: Run no. (2)	Discharge, Q cubic centimeters per second (3)	Width of flume, B centimeters (4)	Mean water depth, D centimeters (5)	Water surface slope, S (6)	Water temperature degrees centigrade (7)	Velocity centimeters per second: Mean V_m (8)	Velocity centimeters per second: Bottom V_b (9)	Hydraulic radius of bed, r_b centimeters (10)	Friction velocity, V^* centimeters per second (11)	Reynolds' Number, R (12)	(1) Manning's n of bed, n_b (13)	Unit discharge, q_b cubic centimeters per sec. per centimeter (14)	Rate of bed movement, G (2) grams per second per centimeter (15)	(2) Suspended load grams per second per centimeter (15A)	Duration of run minutes (16)	Bed condition (17)
									SAND 8								
32	15	3,964	70.5	2.29	0.0010	16.9	24.55	23.47	2.15	1.45	4,856	0.0099	52.8	0.00041	–	60	Smooth
"	16	4,672	"	2.50	"	17.0	26.51	25.91	2.34	1.51	5,700	0.0097	62.0	0.00041	–	60	"
"	20	12,035	"	8.41	"	18.0	20.30	14.94	8.04	2.81	15,437	0.0288	163.2	0.00041	–	60	General Riffles
"	21	14,300	"	9.45	"	18.0	21.46	18.59	8.99	2.97	18,250	0.0293	192.9	0.00083	–	60	"
"	22	22,653	"	11.64	"	18.0	27.60	20.12	10.82	3.26	28,261	0.0259	298.6	0.01158	–	90	"
"	23	32,706	"	13.56	"	18.0	34.21	25.91	12.26	3.47	39,676	0.0229	419.4	0.04299	–	60	"
"	24	43,183	"	16.46	"	18.2	37.21	27.74	14.66	3.79	51,934	0.0288	545.2	0.05911	0.04423	56	"
"	25	62,212	"	18.38	"	18.0	48.01	30.78	15.41	3.89	69,998	0.0189	739.8	0.19512	0.14717	60	"
33	12	10,930	70.5	6.71	0.0015	16.5	23.10	18.59	6.44	3.08	13,524	0.0269	148.8	0.00455	–	60	General Riffles
"	13	17,981	"	9.02	"	16.8	28.28	23.47	8.54	3.54	22,149	0.0265	241.5	0.02191	–	60	"
"	14	25,485	"	11.37	"	16.8	31.79	26.82	10.65	3.96	31,052	0.0275	338.6	0.03059	–	60	"
"	15	35,538	"	14.63	"	16.9	34.46	25.91	13.58	4.47	43,008	0.0297	468.0	0.06490	0.01323	60	"
"	16	49,130	"	18.04	"	16.9	38.63	24.99	16.50	4.93	58,581	0.0302	637.4	0.15667	0.06904	45	"
"	17	63,373	"	20.85	"	17.0	43.11	35.97	18.74	5.25	74,387	0.0293	807.9	0.23687	0.10955	30	Sand Waves
34	7	4,531	70.5	3.90	0.0020	17.5	16.48	–	3.83	2.74	5,890	0.0309	63.1	0.00165	–	60	General Riffles
"	8	5,748	"	4.54	"	17.5	17.96	–	4.44	2.95	7,452	0.0312	79.7	0.00248	–	85	"
"	9	8,014	"	5.61	"	17.6	20.26	14.33	5.46	3.27	10,361	0.0316	110.6	0.00207	–	60	"
"	10	13,167	"	8.17	"	17.8	22.86	15.54	7.92	3.94	17,040	0.0361	181.1	0.01654	–	60	"
"	17	22,937	"	10.82	"	18.0	30.07	22.25	10.31	4.50	29,325	0.0336	310.0	0.08144	0.00289	45	"
"	12	31,998	"	12.44	"	18.2	36.48	26.82	11.65	4.78	40,486	0.0292	425.0	0.16122	0.01240	30	"
"	13	49,781	"	13.56	"	18.2	52.07	28.65	12.11	4.87	60,039	0.0210	630.6	0.32782	0.08681	20	Sand Waves
									SAND 9								
35	15	29,450	70.5	7.38	0.0030	19.2	56.60	63.40	6.71	4.44	37,136	0.0159	379.8	0.00041	No Observations	60	Smooth
"	16	35,113	"	8.23	"	19.4	60.52	75.90	7.41	4.67	44,035	0.0160	448.5	0.00248		60	"
"	17	40,776	"	9.30	"	19.6	62.19	59.74	8.33	4.95	51,139	0.0168	518.0	0.00413		60	"
"	18	47,997	"	10.42	"	19.8	65.34	65.23	9.25	5.22	59,986	0.0171	604.4	0.00661		45	"
"	19	55,020	"	11.52	"	19.9	67.75	58.52	10.16	5.47	68,465	0.0175	688.3	0.00620		45	"
"	20	62,863	"	13.53	"	19.8	65.90	56.69	11.99	5.94	78,413	0.0201	790.1	0.08392		45	Small Scours
36	15	27,184	70.5	6.83	0.0040	18.5	56.45	88.09	6.33	4.98	34,265	0.0177	357.3	0.00331		60	Smooth
"	16	32,989	"	7.68	"	18.2	60.93	56.39	7.06	5.26	40,945	0.0177	430.2	0.00951		60	"
"	17	38,228	"	8.38	"	18.1	64.71	54.25	7.63	5.47	46,901	0.0175	493.7	0.06821		60	"
"	18	43,891	"	9.20	"	18.2	67.67	58.83	8.33	5.74	53,666	0.0178	567.8	0.09963		40	Scours
"	19	48,280	"	9.97	"	18.3	68.69	56.69	9.00	5.94	58,957	0.0184	618.2	0.13476		30	"
37	15	26,759	70.5	6.46	0.0045	19.2	58.76	63.70	6.01	5.15	34,509	0.0180	353.1	0.00207		60	Smooth
"	16	31,432	"	7.07	"	19.5	63.06	58.83	6.52	5.36	40,489	0.0171	411.2	0.01364		60	"
"	17	34,547	"	7.71	"	19.6	63.56	54.56	7.10	5.60	44,561	0.0181	451.3	0.03266		60	"
"	18	40,493	"	8.60	"	20.0	66.79	56.69	7.86	5.89	52,327	0.0184	525.0	0.09053		30	Scours
"	19	47,289	"	9.57	"	20.0	70.09	68.28	8.69	6.19	60,705	0.0187	608.6	0.16453		30	"
"	20	55,161	"	10.70	"	20.0	73.12	71.02	9.66	6.53	70,393	0.0193	706.3	0.21579		22	"
"	21	63,033	"	12.19	"	20.0	73.35	76.20	10.99	6.96	80,400	0.0209	806.1	0.18024		20	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 32
U.S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS
SAND 10

Author's references							Velocity centimeters per second									
Table	Run Number	Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Mean V_m	Bottom V_b	Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND 10																
RISING STAGE																
5	10	15,744	70.5	6.46	0.0010	15.1	34.56	No Observations	5.83	2.39	17,674	0.0138	201.5	0.00136	60	Smooth
″	11	18,264	″	7.07	″	14.8	36.64		6.32	2.49	20,136	0.0136	231.6	0.00492	60	Local Waves
″	12	20,643	″	7.65	″	14.7	38.27		6.78	2.58	22,504	0.0138	259.5	0.00591	60	″
″	13	23,248	″	8.29	″	14.6	39.78		7.29	2.67	25,086	0.0139	290.0	0.01815	60	″
″	14	26,080	″	8.87	″	14.6	41.71		7.71	2.75	27,819	0.0137	321.6	0.03026	60	General Waves
″	15	29,591	″	9.63	″	14.6	43.58		8.29	2.85	31,252	0.0138	361.3	0.02782	206	″
″	17	32,848	″	10.39	″	14.8	44.83		8.89	2.95	34,656	0.0141	398.5	0.04043	120	″
″	18	32,848	″	10.45	″	14.9	44.57		8.96	2.96	34,847	0.0142	399.3	0.04977	85	″
″	19	32,848	″	10.52	″	15.0	44.31		9.03	2.98	35,037	0.0144	400.1	0.04175	131	″
″	20	36,670	″	10.97	″	15.4	47.40		9.24	3.01	38,725	0.0136	438.0	0.06594	173	″
″	21	39,360	″	11.86	″	15.5	47.09		10.02	3.14	41,793	0.0146	471.8	0.05663	123	″
″	22	45,024	″	14.39	″	16.0	44.39		12.33	3.48	49,088	0.0176	547.3	0.04961	121	″
″	23	49,016	″	15.51	″	16.3	44.82		13.26	3.61	53,735	0.0184	594.3	0.05841	145	″
″	24	53,377	″	16.18	″	16.4	46.78		13.70	3.67	58,157	0.0180	640.9	0.06325	120	″
″	25	58,248	″	17.59	″	16.5	46.98		14.86	3.82	63,466	0.0189	698.1	0.07784	120	″
″	26	62,552	″	19.48	″	16.7	45.56		16.57	4.03	69,006	0.0209	754.9	0.10955	106	″
FALLING STAGE																
6	27	62,382	70.5	19.66	0.0010	15.1	45.01	No Observations	16.79	4.06	66,291	0.0213	755.7	0.08847	105	General Waves
″	28	58,559	″	18.17	″	15.3	45.73		15.45	3.89	62,249	0.0199	706.5	0.06784	70	″
″	29	54085	″	16.98	″	15.8	45.19		14.50	3.77	58,505	0.0193	655.3	0.05676	123	″
″	31	48,733	″	15.06	″	16.8	45.91		12.78	3.54	53,828	0.0174	586.7	0.03857	152	″
″	32	45,307	″	14.39	″	17.2	44.67		12.30	3.47	50,874	0.0174	549.4	0.03969	173	″
″	33	39,502	″	12.01	″	16.2	46.66		10.17	3.16	42,751	0.0148	474.5	0.07420	60	″
″	34	36,812	″	11.09	″	16.2	47.06		9.36	3.03	39,683	0.0138	440.5	0.04899	139	″
″	35	32,423	″	10.61	″	16.4	43.36		9.15	3.00	36,002	0.0148	396.7	0.03745	117	″
″	36	29,704	″	9.85	″	15.7	42.80		8.52	2.89	32,443	0.0143	364.7	0.03270	126	″
″	37	26,052	″	9.11	″	15.7	40.55		7.98	2.80	28,789	0.0144	323.6	0.03034	171	″
″	38	23,220	″	8.38	″	15.7	39.29		7.38	2.69	25,797	0.0142	290.0	0.01426	70	″
″	39	23,220	″	8.38	″	15.4	39.29		7.38	2.69	25,638	0.0142	290.0	0.01877	133	″
″	40	20,700	″	7.83	″	15.4	37.48		6.96	2.61	23,065	0.0143	260.9	0.01716	65	Local Waves
″	41	20,756	″	7.83	″	15.5	37.58		6.96	2.61	23,167	0.0143	261.6	0.01856	63	″
″	42	18,264	″	6.98	″	15.4	37.12		6.21	2.47	20,382	0.0133	230.5	0.01600	65	Smooth
″	43	18,264	″	6.98	″	15.4	37.12		6.21	2.47	20,382	0.0133	230.5	0.01302	90	″
″	44	15,772	″	6.19	″	15.6	36.16		5.54	2.33	17,775	0.0128	200.3	0.00628	61	″
RISING STAGE																
7	8	9,883	70.5	4.11	0.0015	15.8	34.06	No Observations	3.82	2.37	11,620	0.0129	130.1	0.00219	70	Smooth
″	9	12,205	″	4.69	″	15.9	36.88		4.32	2.52	14,264	0.0130	159.3	0.01286	60	″
″	10	15,829	″	5.46	″	15.9	41.15		4.94	2.70	18,200	0.0127	203.3	0.03340	90	Local Waves
″	11	19,397	″	6.40	″	15.7	42.98		5.76	2.91	22,028	0.0134	247.6	0.04518	60	General Waves
″	12	21,238	″	6.77	″	15.8	44.52		6.05	2.98	24,049	0.0134	269.3	0.06317	109	″
″	13	23,475	″	7.13	″	16.0	46.68		6.32	3.05	26,462	0.0132	295.1	0.05849	91	″
″	14	23,503	″	7.22	″	16.1	46.15		6.42	3.07	26,621	0.0135	296.3	0.06284	74	″
″	15	25,768	″	7.71	″	16.3	47.39		6.82	3.17	29,228	0.0137	323.3	0.07032	73	″
″	16	29,591	″	8.75	″	16.5	47.98		7.72	3.37	33,675	0.0147	370.4	0.08193	102	″
″	17	32,423	″	9.45	″	16.7	48.67		8.30	3.49	36,927	0.0151	404.0	0.08847	99	″
″	18	36,529	″	10.30	″	16.4	50.29		8.99	3.64	41,030	0.0155	452.2	0.11286	58	″
″	19	39,644	″	10.94	″	16.4	51.39		9.50	3.74	44302	0.0156	488.2	0.12505	80	″
″	20	44,457	″	11.98	″	16.6	52.64		10.34	3.90	49,576	0.0162	544.3	0.16784	48	″
″	21	44,457	″	12.07	″	16.7	52.24		10.45	3.92	49,905	0.0165	546.0	0.14386	31	″
″	22	48,478	″	13.05	″	16.8	52.71		11.27	4.07	54,501	0.0171	594.1	0.15027	75	″
″	23	52,924	″	13.50	″	17.1	55.59		11.52	4.12	59,086	0.0166	640.5	0.17610	56	″
″	24	57,625	″	14.51	″	16.5	56.33		12.32	4.26	63,099	0.0170	694.1	0.20091	66	″
″	25	62,042	″	16.46	″	16.5	53.46		14.17	4.57	68,877	0.0198	757.6	0.19677	50	″
″	26	62,212	″	16.46	″	16.6	53.61		14.15	4.56	69,094	0.0196	758.6	0.25258	87	″
″	27	62,382	″	16.43	″	17.3	53.86		14.12	4.56	70,615	0.0195	760.5	0.20628	58	″
FALLING STAGE																
8	28	57,002	70.5	15.45	0.0015	17.6	52.32	No Observations	13.37	4.44	65,500	0.0193	699.5	0.22943	57	General Waves
″	29	57,002	″	15.79	″	17.7	51.21		13.73	4.49	66,083	0.0202	703.1	0.18313	45	″
″	30	52,471	″	15.00	″	17.9	49.63		13.13	4.40	61,479	0.0201	651.7	0.19429	41	″
″	31	48,422	″	13.75	″	18.0	49.96		12.02	4.21	56,820	0.0189	600.6	0.12319	84	″
″	32	44,457	″	12.62	″	18.2	49.97		11.03	4.03	52,497	0.0178	551.2	0.07805	120	″
″	33	40,068	″	11.77	″	18.4	48.30		10.35	3.90	47,800	0.0176	500.0	0.08557	49	″

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 32 (CONTINUED)
U.S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS
SAND 10

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, $G^{(2)}$ grams per second per centimeter	Duration of run minutes	Bed condition
Table	Run Number						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND 10 (CONTINUED)																
FALLING STAGE																
8	34	36,246	70.5	10.79	0.0015	18.2	47.64	No Observations	9.52	3.74	43,202	0.0169	453.6	0.10913	50	General Waves
"	35	36,246	"	10.82	"	18.2	47.51		9.56	3.75	43,261	0.0171	454.2	0.07400	41	"
"	36	31,573	"	9.81	"	18.2	45.63		8.73	3.58	37,939	0.0167	398.4	0.05300	62	"
"	37	28,175	"	9.02	"	18.4	44.29		8.08	3.45	34,219	0.0164	357.9	0.08350	71	"
"	38	28,175	"	9.02	"	18.5	44.29		8.08	3.45	34,317	0.0164	357.9	0.06056	104	"
"	39	25,513	"	8.05	"	18.7	44.97		7.19	3.25	31,213	0.0150	323.4	0.05052	35	"
"	40	23,220	"	7.53	"	18.7	43.74		6.76	3.15	28,546	0.0147	295.7	0.08061	40	"
"	41	23,220	"	7.53	"	18.7	43.74		6.76	3.15	28,546	0.0147	295.7	0.05358	81	"
"	42	21,238	"	6.95	"	17.4	43.34		6.25	3.03	25,203	0.0141	270.9	0.03911	60	"
"	43	19,255	"	6.43	"	17.5	42.46		5.80	2.92	22,999	0.0137	246.3	0.04899	55	"
"	44	19,255	"	6.43	"	17.5	42.46		5.80	2.92	22,999	0.0137	246.3	0.05002	58	Local Waves
"	45	15,801	"	5.49	"	17.4	40.85		4.98	2.71	18,925	0.0128	203.4	0.01848	50	"
"	46	12,176	"	4.48	"	17.3	38.54		4.10	2.46	14,675	0.0120	158.0	0.02055	36	Smooth
"	47	9,911	"	3.78	"	17.3	37.19		3.47	2.26	11,984	0.0111	129.1	0.00694	54	"
RISING STAGE																
9	8	9,911	70.5	3.93	0.0020	15.0	35.75	No Observations	3.69	2.69	11,551	0.0139	131.9	0.00831	49	Smooth
"	9	12,828	"	4.66	"	15.0	39.02		4.34	2.92	14,829	0.0142	169.3	0.02733	60	"
"	10	15,857	"	5.30	"	14.9	42.41		4.89	3.10	18,096	0.0141	207.4	0.05903	60	Local Waves
"	11	19,510	"	6.07	"	14.8	45.63		5.54	3.30	21,982	0.0143	252.8	0.07544	48	General Waves
"	12	21,521	"	6.34	"	14.4	48.15		5.74	3.36	23,785	0.0139	276.4	0.10459	58	"
"	13	23,220	"	6.74	"	14.3	48.90		6.08	3.45	25,498	0.0142	297.3	0.09839	71	"
"	14	25,627	"	7.47	"	14.3	48.68		6.75	3.64	28,181	0.0152	328.6	0.09425	60	"
"	15	29,450	"	8.20	"	14.3	50.95		7.35	3.80	32,117	0.0155	374.5	0.11348	49	"
"	16	32,423	"	8.84	"	14.3	52.03		7.89	3.93	35,207	0.0158	410.5	0.12815	47	"
"	17	36,585	"	9.60	"	14.3	54.05		8.52	4.09	39,495	0.0161	460.5	0.14014	42	"
"	18	40,097	"	10.45	"	13.9	54.40		9.26	4.26	42,763	0.0168	503.7	0.15874	39	"
"	19	44,118	"	11.00	"	14.0	56.87		9.67	4.36	46,803	0.0166	549.9	0.14345	48	"
"	20	48,620	"	11.95	"	14.2	57.72		10.46	4.53	51,603	0.0172	603.8	0.24927	46	"
"	21	48,620	"	11.95	"	14.3	57.72		10.46	4.53	51,780	0.0172	603.8	0.26126	48	"
"	22	53,207	"	13.32	"	13.9	56.66		11.70	4.79	56,275	0.0189	662.9	0.22488	40	"
"	23	57,625	"	15.09	"	13.9	54.18		13.39	5.12	61,585	0.0217	725.5	0.29847	34	"
"	24	62,552	"	16.55	"	13.9	53.61		14.69	5.37	66,853	0.0232	787.5	0.27490	26	"
"	25	62,552	"	16.73	"	13.9	53.02		14.89	5.40	67,018	0.0237	789.5	0.25548	25	"
FALLING STAGE																
10	26	55,161	70.5	15.42	0.0020	13.9	50.73	No Observations	13.84	5.21	59,601	0.0237	702.1	0.24927	36	General Waves
"	27	47,912	"	13.69	"	14.0	49.66		12.32	4.92	52,069	0.0223	611.8	0.11947	47	"
"	28	41,088	"	11.67	"	14.3	49.92		10.50	4.54	44,954	0.0200	524.2	0.13559	41	"
"	29	35,113	"	10.36	"	14.5	48.06		9.38	4.29	38,929	0.0192	450.8	0.09033	48	"
"	30	28,912	"	8.75	"	14.5	46.88		7.94	3.95	32,144	0.0175	372.2	0.06788	39	"
"	31	23,645	"	7.32	"	14.5	45.85		6.67	3.62	26,409	0.0161	305.8	0.09384	50	"
"	32	19,312	"	6.25	"	14.5	43.84		5.73	3.35	21,693	0.0152	251.2	0.07342	53	"
"	33	15,659	"	5.09	"	14.5	43.64		4.67	3.03	17,599	0.0133	203.8	0.04853	62	Local Waves
"	34	12,205	"	4.24	"	14.5	40.86		3.92	2.77	13,832	0.0127	160.2	0.02633	105	"
"	35	9,883	"	3.54	"	14.6	39.65		3.28	2.54	11,250	0.0116	130.1	0.01451	59	Smooth
"	36	6,881	"	2.83	"	14.8	34.43		2.67	2.29	7,994	0.0116	91.9	0.01013	65	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 33
U. S. WATERWAYS EXPERIMENT STATION EXPERIMENTS ON THE EFFECT OF TURBIDITY ON BED-LOAD TRANSPORTATION.

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per sec. per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Turbidity of water parts per million by weight	Duration of run minutes	Bed condition
Test Number	Run Number						Mean V_m	Bottom V_b									
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(15A)	(16)	(17)
1	3	6,570	30.48	6.10	0.0010	17.0	35.36		5.02	2.22	16,355	0.0128	177.5	0.01819	0	60	Smooth
"	4	"	"	"	"	16.0	"		"	"	15,929	"	"	0.02150	"	"	"
"	5	"	"	"	"	16.0	"		"	"	15,929	"	"	0.01612	"	"	"
"	6	"	"	"	"	15.9	"		"	"	15,901	"	"	0.01612	"	"	"
"	7	"	"	"	"	15.9	"		"	"	15,901	"	"	0.01778	"	"	"
"	8	"	"	"	"	15.9	"		"	"	15,901	"	"	0.01695	"	"	"
"	9	"	"	"	"	15.9	"		"	"	15,901	"	"	0.01778	"	"	"
"	10	"	"	"	"	15.9	"		"	"	15,901	"	"	0.01612	"	"	"
"	11	"	"	"	"	15.9	"		"	"	15,901	"	"	0.01406	"	"	"
"	12	"	"	"	"	15.9	"		"	"	15,901	"	"	0.01406	"	"	"
"	13	"	"	"	"	15.8	"		"	"	15,858	"	"	0.01571	"	"	Local Riffles
"	14	"	"	"	"	15.8	"		"	"	15858	"	"	0.01571	"	"	" "
"	15	"	"	"	"	15.8	"		"	"	15858	"	"	0.01364	"	"	" "
2	1	23,871	30.48	15.24	0.0010	14.6	51.39		10.54	3.21	46,869	0.0137	541.7	0.09301	"	"	Riffles
"	2	"	"	"	"	14.6	"		"	"	46,869	"	"	0.10459	"	30	"
"	3	"	"	"	"	14.7	"		"	"	46,991	"	"	0.09094	"	60	"
"	4	"	"	"	"	14.8	"		"	"	47,113	"	"	0.10128	"	"	"
"	5	"	"	"	"	14.9	"		"	"	47,278	"	"	0.13228	"	"	"
"	6	"	"	"	"	15.0	"		"	"	47,444	"	"	0.09094	"	"	"
"	7	"	"	"	"	14.2	"		"	"	46,308	"	"	0.09921	"	"	"
"	8	"	"	"	"	14.2	"		"	"	46,308	"	"	0.10128	"	"	"
"	9	"	"	"	"	14.2	"		"	"	46,308	"	"	0.10128	"	"	"
"	10	"	"	"	"	14.3	"		"	"	46,467	"	"	0.13848	"	"	"
"	11	"	"	"	"	14.3	"		"	"	46,467	"	"	0.08888	"	"	"
"	12	"	"	"	"	14.3	"		"	"	46,467	"	"	0.10748	"	"	"
"	13	"	"	"	"	14.5	"		"	"	46,748	"	"	0.09921	"	"	"
3	1	23,871	30.48	15.24	0.0010	9.8	51.39	No Observations	10.54	3.21	41,096	0.0137	541.7	0.07978	197	45	Riffles
"	2	"	"	"	"	10.4	"		"	"	41,826	"	"	0.07441	171	30	"
"	3	"	"	"	"	11.5	"		"	"	43,159	"	"	0.08474	171	60	"
"	4	"	"	"	"	11.7	"		"	"	43,367	"	"	0.09921	161	"	"
"	5	"	"	"	"	11.9	"		"	"	43,611	"	"	0.10748	148	"	"
"	6	"	"	"	"	12.2	"		"	"	43,965	"	"	0.08268	133	"	"
"	7	"	"	"	"	12.5	"		"	"	44,325	"	"	0.08681	136	"	"
"	8	"	"	"	"	12.7	"		"	"	44,580	"	"	0.09715	139	"	"
"	9	"	"	"	"	14.2	"		"	"	46,295	"	"	0.08061	131	"	"
"	10	"	"	"	"	14.3	"		"	"	46,494	"	"	0.09301	132	"	"
"	11	"	"	"	"	14.7	"		"	"	46,978	"	"	0.12815	133	"	"
"	12	"	"	"	"	15.0	"		"	"	47,430	"	"	0.08888	133	"	"
"	13	"	"	"	"	–	"		"	"	47,430	"	"	0.10955	132	"	"
4	1	6,570	30.48	6.10	0.0010	16.1	35.36		5.02	2.22	15,958	0.0128	177.5	0.01488	131	"	Smooth
"	2	"	"	"	"	16.1	"		"	"	15,958	"	"	0.01571	126	"	"
"	3	"	"	"	"	16.2	"		"	"	16,001	"	"	0.01612	121	"	"
"	4	"	"	"	"	16.3	"		"	"	16,059	"	"	0.01364	117	"	"
"	5	"	"	"	"	16.6	"		"	"	16,176	"	"	0.01447	116	"	"
"	6	"	"	"	"	16.9	"		"	"	16,325	"	"	0.01406	116	"	"
"	7	"	"	"	"	17.0	"		"	"	16,355	"	"	0.01406	115	"	"
"	8	"	"	"	"	17.1	"		"	"	16,400	"	"	0.01364	114	"	"
"	9	"	"	"	"	17.2	"		"	"	16,446	"	"	0.01281	112	"	"
"	10	"	"	"	"	17.5	"		"	"	16,584	"	"	0.01364	111	"	"
5a	1	23,871	30.48	15.24	0.0010	18.3	51.39		10.54	3.21	51,684	0.0137	541.7	0.11988	327	"	Riffles
"	2	"	"	"	"	18.3	"		"	"	51,684	"	"	0.11575	306	"	"
"	3	"	"	"	"	18.5	"		"	"	51,932	"	"	0.16122	285	"	"
"	4	"	"	"	"	19.0	"		"	"	52,536	"	"	0.08268	263	"	"
"	5	"	"	"	"	19.2	"		"	"	52,947	"	"	0.14055	258	"	"
"	6	"	"	"	"	19.2	"		"	"	52,947	"	"	0.14882	252	"	"
"	7	"	"	"	"	19.2	"		"	"	52,947	"	"	0.13228	247	"	"
"	8	"	"	"	"	19.2	"		"	"	52,947	"	"	0.14055	241	"	"
"	9	"	"	"	"	19.2	"		"	"	52,947	"	"	0.09508	234	"	"
"	10	"	"	"	"	19.5	"		"	"	53,312	"	"	0.20669	227	"	"
"	11	"	"	"	"	19.5	"		"	"	53,312	"	"	0.10748	220	"	"
"	12	"	"	"	"	19.7	"		"	"	53,639	"	"	0.14882	216	"	"
"	13	"	"	"	"	19.8	"		"	"	53,735	"	"	0.15915	211	"	"
"	14	"	"	"	"	19.9	"		"	"	53,896	"	"	0.15089	206	"	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 33 (CONTINUED)
U. S. WATERWAYS EXPERIMENT STATION EXPERIMENTS ON THE EFFECT OF TURBIDITY ON BED-LOAD TRANSPORTATION

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, qb cubic centimeters per sec. per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Turbidity of water parts per million by weight	Duration of run minutes	Bed condition
Test Number	Run Number						Mean V_m	Bottom V_b									
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(15A)	(16)	(17)
56	16	23,871	30.48	15.24	0.0010	20.0	51.39	No Observations	10.54	3.21	54,003	0.0137	541.7	0.09301	197	60	Riffles
"	17	"	"	"	"	20.3	"		"	"	54,383	"	"	0.12608	193	"	"
"	18	"	"	"	"	20.5	"		"	"	54,712	"	"	0.09301	189	"	"
"	19	"	"	"	"	20.5	"		"	"	54,712	"	"	0.15915	185	"	"
"	20	"	"	"	"	20.5	"		"	"	54,712	"	"	0.09921	183	"	"
"	21	"	"	"	"	20.3	"		"	"	54,383	"	"	0.10128	181	"	"
"	22	"	"	"	"	20.3	"		"	"	54,383	"	"	0.18396	178	"	"
"	23	"	"	"	"	20.5	"		"	"	54,712	"	"	0.11368	171	"	"
"	24	"	"	"	"	20.5	"		"	"	54,712	"	"	0.11161	164	"	"
"	25	"	"	"	"	20.6	"		"	"	54,823	"	"	0.12815	157	"	"
"	26	"	"	"	"	20.6	"		"	"	54,823	"	"	0.11368	147	"	"
"	27	"	"	"	"	20.6	"		"	"	54,823	"	"	0.13228	137	"	"
"	28	"	"	"	"	20.6	"		"	"	54,823	"	"	0.11368	128	"	"
"	29	"	"	"	"	20.8	"		"	"	55,102	"	"	0.17569	118	"	"
"	30	"	"	"	"	20.8	"		"	"	55,102	"	"	0.12402	109	"	"
"	31	"	"	"	"	20.8	"		"	"	55,102	"	"	0.14262	100	"	"
6	1	6,570	30.48	6.10	0.0010	21.0	35.36		5.02	2.22	18,161	0.0128	177.5	0.01819	252	60	Smooth
"	2	"	"	"	"	21.2	"		"	"	18,273	"	"	0.01612	259	"	"
"	3	"	"	"	"	21.3	"		"	"	18,311	"	"	0.01654	266	"	"
"	4	"	"	"	"	21.5	"		"	"	18,386	"	"	0.01612	273	"	"
"	5	"	"	"	"	21.5	"		"	"	18,386	"	"	0.01571	237	"	"
"	6	"	"	"	"	21.5	"		"	"	18,386	"	"	0.01571	200	"	"
"	7	"	"	"	"	21.5	"		"	"	18,386	"	"	0.01530	164	"	"
"	8	"	"	"	"	21.5	"		"	"	18,386	"	"	0.01447	162	"	"
"	9	"	"	"	"	21.6	"		"	"	18,425	"	"	0.01654	160	"	Riffles
"	10	"	"	"	"	21.8	"		"	"	18,521	"	"	0.01612	157	"	Smooth
"	11	"	"	"	"	21.8	"		"	"	18,521	"	"	0.01819	163	"	"
"	12	"	"	"	"	21.9	"		"	"	18,559	"	"	0.01612	169	"	"
"	13	"	"	"	"	22.0	"		"	"	18,598	"	"	0.01488	174	"	"
7	1	23,871	30.48	15.24	0.0010	22.7	51.39		10.54	3.21	57,807	0.0137	541.7	0.15295	690	60	Riffles
"	2	"	"	"	"	22.7	"		"	"	57,807	"	"	0.15502	603	"	"
"	3	"	"	"	"	22.8	"		"	"	57,931	"	"	0.18189	516	"	"
"	4	"	"	"	"	23.0	"		"	"	58,242	"	"	0.15915	428	"	"
"	5	"	"	"	"	22.8	"		"	"	57,931	"	"	0.16535	421	"	"
"	6	"	"	"	"	22.8	"		"	"	57,931	"	"	0.16949	414	"	"
"	7	"	"	"	"	22.8	"		"	"	57,931	"	"	0.16122	406	"	"
"	8	"	"	"	"	23.0	"		"	"	58,242	"	"	0.24390	404	"	"
"	9	"	"	"	"	23.2	"		"	"	57,931	"	"	0.13642	402	"	"
"	10	"	"	"	"	23.2	"		"	"	57,931	"	"	0.21083	400	"	"
"	11	"	"	"	"	23.2	"		"	"	57,931	"	"	0.15915	412	"	"
"	12	"	"	"	"	23.2	"		"	"	57,931	"	"	0.25630	425	"	"
"	13	"	"	"	"	23.5	"		"	"	58,875	"	"	0.15295	437	"	"
"	14	"	"	"	"	23.5	"		"	"	58,875	"	"	0.28937	435	"	"
8	1	6,570	30.48	6.10	0.0010	23.8	35.36		5.02	2.22	19,433	0.0128	177.5	0.01488	389	60	Smooth
"	2	"	"	"	"	23.8	"		"	"	19,433	"	"	0.01447	380	"	"
"	3	"	"	"	"	23.8	"		"	"	19,433	"	"	0.01447	371	"	"
"	4	"	"	"	"	23.9	"		"	"	19,475	"	"	0.01323	363	"	"
"	5	"	"	"	"	24.0	"		"	"	19,518	"	"	0.01571	353	"	"
"	6	"	"	"	"	24.1	"		"	"	19,518	"	"	0.01488	344	"	"
"	7	"	"	"	"	24.2	"		"	"	19,647	"	"	0.01488	336	"	"
"	8	"	"	"	"	24.2	"		"	"	19,647	"	"	0.01447	311	"	"
"	9	"	"	"	"	24.2	"		"	"	19,647	"	"	0.01571	286	"	"
"	10	"	"	"	"	24.2	"		"	"	19,647	"	"	0.01447	262	"	"
9	1	23,871	30.48	15.24	0.0010	25.3	51.39		10.54	3.21	61,342	0.0137	541.7	0.12402	673	60	Riffles
"	2	"	"	"	"	25.3	"		"	"	61,342	"	"	0.18602	673	"	"
"	3	"	"	"	"	25.3	"		"	"	61,342	"	"	0.24803	674	"	"
"	4	"	"	"	"	25.2	"		"	"	61,203	"	"	0.22943	674	"	"
"	5	"	"	"	"	25.2	"		"	"	61,203	"	"	0.26457	601	"	"
"	6	"	"	"	"	25.2	"		"	"	61,203	"	"	0.16535	528	"	"
"	7	"	"	"	"	25.2	"		"	"	61,203	"	"	0.14469	456	"	"
"	8	"	"	"	"	25.2	"		"	"	61,203	"	"	0.24183	440	"	"
"	9	"	"	"	"	25.2	"		"	"	61,203	"	"	0.14469	424	"	"
"	10	"	"	"	"	25.2	"		"	"	61,203	"	"	0.22323	407	"	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 33 (CONTINUED)
U. S. WATERWAYS EXPERIMENT STATION EXPERIMENTS ON THE EFFECT OF TURBIDITY ON BED-LOAD TRANSPORTATION

Author's references							Velocity centimeters per second										
Test Number (1)	Run Number (2)	Discharge, Q cubic centimeters per second (3)	Width of flume, B centimeters (4)	Mean water depth, D centimeters (5)	Water surface slope, S (6)	Water temperature degrees centigrade (7)	Mean V_m (8)	Bottom V_b (9)	Hydraulic radius of bed, r_b centimeters (10)	Friction velocity, V' centimeters per second (11)	Reynolds Number, R (12)	Manning's n of bed, n_b (1) (13)	Unit discharge, qb cubic centimeters per sec. per centimeter (14)	Rate of bed movement, G (2) grams per second per centimeter (15)	Turbidity of water parts per million by weight (15A)	Duration of run minutes (16)	Bed condition (17)
10	1	6,570	30.48	6.10	0.0010	25.1	35.36		5.02	2.22	20,024	0.0128	177.5	0.01654	536	60	Smooth
"	2	"	"	"	"	25.1	"		"	"	20,024	"	"	0.01654	530	"	"
"	3	"	"	"	"	25.1	"		"	"	20,024	"	"	0.01612	524	"	"
"	4	"	"	"	"	25.0	"		"	"	19,957	"	"	0.01819	517	"	"
"	5	"	"	"	"	25.0	"		"	"	19,957	"	"	0.01860	486	"	"
"	6	"	"	"	"	25.0	"		"	"	19,957	"	"	0.01778	455	"	"
"	7	"	"	"	"	25.0	"		"	"	19,957	"	"	0.01488	425	"	"
"	8	"	"	"	"	25.0	"		"	"	19,957	"	"	0.01488	406	"	"
"	9	"	"	"	"	25.0	"		"	"	19,957	"	"	0.01612	387	"	"
"	10	"	"	"	"	25.0	"		"	"	19,957	"	"	0.01654	369	"	"
11	1	23,871	30.48	15.24	0.0010	24.5	51.39		10.54	3.21	60,250	0.0137	541.7	0.14469	699	60	Riffles
"	2	"	"	"	"	24.5	"		"	"	60,250	"	"	0.25217	688	"	"
"	3	"	"	"	"	24.5	"		"	"	60,250	"	"	0.16329	677	"	"
"	4	"	"	"	"	24.5	"		"	"	60,250	"	"	0.31831	666	"	"
"	5	"	"	"	"	24.7	"		"	"	60,452	"	"	0.16949	633	"	"
"	6	"	"	"	"	24.2	"		"	"	59,917	"	"	0.22530	600	"	"
"	7	"	"	"	"	24.2	"		"	"	59,917	"	"	0.22943	567	"	"
"	8	"	"	"	"	24.2	"		"	"	59,917	"	"	0.23356	601	"	"
"	9	"	"	"	"	24.2	"		"	"	59,917	"	"	0.14262	635	"	"
"	10	"	"	"	"	24.2	"		"	"	59,917	"	"	0.24183	668	"	"
"	11	"	"	"	"	24.2	"		"	"	59,917	"	"	0.16949	624	"	"
12	1	6,570	30.48	6.10	0.0010	24.0	35.36		5.02	2.22	19,518	0.0128	177.5	0.01778	580	60	Smooth
"	2	"	"	"	"	"	"		"	"	19,518	"	"	0.01695	544	"	"
"	3	"	"	"	"	"	"		"	"	19,518	"	"	0.01736	508	"	"
"	4	"	"	"	"	"	"		"	"	19,518	"	"	0.01571	471	"	"
"	5	"	"	"	"	"	"	No Observations	"	"	19,518	"	"	0.01488	456	"	"
"	6	"	"	"	"	"	"		"	"	19,518	"	"	0.01488	442	"	"
"	7	"	"	"	"	"	"		"	"	19,518	"	"	0.01612	427	"	"
13	1	23,871	30.48	15.24	0.0010	24.2	51.39		10.54	3.21	59,917	0.0137	541.7	0.17362	805	60	Riffles
"	2	"	"	"	"	24.2	"		"	"	59,917	"	"	0.23770	783	"	"
"	3	"	"	"	"	24.2	"		"	"	59,917	"	"	0.28524	761	"	"
"	4	"	"	"	"	24.0	"		"	"	59,522	"	"	0.23356	738	"	"
"	5	"	"	"	"	24.0	"		"	"	59,522	"	"	0.27283	693	"	"
"	6	"	"	"	"	24.0	"		"	"	59,522	"	"	0.15089	648	"	"
"	7	"	"	"	"	24.0	"		"	"	59,522	"	"	0.22323	602	"	"
"	8	"	"	"	"	24.0	"		"	"	59,522	"	"	0.15709	623	"	"
"	9	"	"	"	"	24.0	"		"	"	59,522	"	"	0.23976	644	"	"
"	10	"	"	"	"	24.0	"		"	"	59,522	"	"	0.27283	665	"	"
14	1	6,570	30.48	6.10	0.0010	24.0	35.36		5.02	2.22	19,518	0.0128	177.5	0.01778	1210	60	Smooth
"	2	"	"	"	"	"	"		"	"	19,518	"	"	0.01612	1175	"	"
"	3	"	"	"	"	"	"		"	"	19,518	"	"	0.01571	1140	"	"
"	4	"	"	"	"	"	"		"	"	19,518	"	"	0.01654	1105	"	"
"	5	"	"	"	"	"	"		"	"	19,518	"	"	0.01281	1072	"	Local Riffles
"	6	"	"	"	"	"	"		"	"	19,518	"	"	0.01819	1049	"	" "
15	1	23,871	30.48	15.24	0.0010	23.0	51.39		10.54	3.21	58,242	0.0137	541.7	0.11575	1026	60	Riffles
"	2	"	"	"	"	23.0	"		"	"	58,242	"	"	0.19843	1019	"	"
"	3	"	"	"	"	23.0	"		"	"	58,242	"	"	0.17776	1008	"	"
"	4	"	"	"	"	23.0	"		"	"	58,242	"	"	0.31004	998	"	"
"	5	"	"	"	"	23.0	"		"	"	58,242	"	"	0.14882	959	"	"
"	6	"	"	"	"	23.0	"		"	"	58,242	"	"	0.22116	920	"	"
"	7	"	"	"	"	23.0	"		"	"	58,242	"	"	0.25630	880	"	"
"	8	"	"	"	"	23.0	"		"	"	58,242	"	"	0.14469	863	"	"
"	9	"	"	"	"	23.0	"		"	"	58,242	"	"	0.35551	846	"	"
"	10	"	"	"	"	23.2	"		"	"	58,430	"	"	0.16742	828	"	"
16	1	6,570	30.48	6.10	0.0010	23.5	35.36		5.02	2.22	19,306	0.0128	177.5	0.01778	750	60	Smooth
"	2	"	"	"	"	23.5	"		"	"	19,306	"	"	0.01778	750	"	"
"	3	"	"	"	"	23.6	"		"	"	19,306	"	"	0.01778	749	"	"
"	4	"	"	"	"	23.5	"		"	"	19,306	"	"	0.01778	727	"	"
"	5	"	"	"	"	23.5	"		"	"	19,306	"	"	0.01819	722	"	"
"	6	"	"	"	"	23.5	"		"	"	19,306	"	"	0.01695	738	"	"
17	1	23,871	30.48	15.24	0.0010	24.1	51.39		10.54	3.21	58,368	0.0137	541.7	0.10541	829	60	Riffles
"	2	"	"	"	"	24.[illegible]	"		"	"	59,522	"	"	0.22323	747	"	"
"	3	"	"	"	"	24.0	"		"	"	59,522	"	"	0.21413	665	"	"
18	1	6,570	30.48	6.10	0.0010	23.1	35.36		5.02	2.22	19,139	0.0128	177.5	0.01199	350	60	Smooth
"	2	"	"	"	"	23.1	"		"	"	19,139	"	"	0.01488	355	"	"
"	3	"	"	"	"	23.1	"		"	"	19,139	"	"	0.01530	360	"	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 33 (CONTINUED)
U. S. WATERWAYS EXPERIMENT STATION EXPERIMENTS ON THE EFFECT OF TURBIDITY ON BED-LOAD TRANSPORTATION.

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per sec. per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Turbidity of water parts per million by weight	Duration of run minutes	Bed condition
Test Number	Run Number						Mean V_m	Bottom V_b									
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(15A)	(16)	(17)
19	1	23,871	30.48	15.24	0.0010	24.0	51.39	No Observations	10.54	3.21	59,522	0.0137	541.7	0.16535	388	60	Riffles
"	2	"	"	"	"	"	"		"	"	"	"	"	0.24803	381	"	"
"	3	"	"	"	"	"	"		"	"	"	"	"	0.19636	374	"	"
"	4	"	"	"	"	"	"		"	"	"	"	"	0.23150	365	"	"
"	5	"	"	"	"	"	"		"	"	"	"	"	0.24803	358	"	"
20	1	6,570	30.48	6.10	0.0010	25.0	35.36		5.02	2.22	19,957	0.0128	177.5	0.02067	252	60	Smooth
"	2	"	"	"	"	"	"		"	"	"	"	"	0.01612	249	"	"
"	3	"	"	"	"	"	"		"	"	"	"	"	0.01819	247	"	"
"	4	"	"	"	"	"	"		"	"	"	"	"	0.01612	245	"	"
"	5	"	"	"	"	"	"		"	"	"	"	"	0.01571	243	"	"
21	1	23,871	30.48	15.24	0.0010	25.5	51.39		10.54	3.21	61,551	0.0137	541.7	0.22116	279	60	Riffles
"	2	"	"	"	"	"	"		"	"	"	"	"	0.20669	262	"	"
"	3	"	"	"	"	"	"		"	"	"	"	"	0.17982	245	"	"
"	4	"	"	"	"	"	"		"	"	"	"	"	0.32244	228	"	"
"	5	"	"	"	"	"	"		"	"	"	"	"	0.15709	230	"	"
22	1	6,570	30.48	6.10	0.0010	25.5	35.36		5.02	2.22	20,183	0.0128	177.5	0.02398	197	60	Smooth
"	2	"	"	"	"	"	"		"	"	"	"	"	0.01819	194	"	"
"	3	"	"	"	"	"	"		"	"	"	"	"	0.01902	192	"	"
"	4	"	"	"	"	"	"		"	"	"	"	"	0.01902	200	"	"
"	5	"	"	"	"	"	"		"	"	"	"	"	0.01571	210	"	"
23	1	23,871	30.48	15.24	0.0010	26.0	51.39		10.54	3.21	62,187	0.0137	541.7	0.26043	248	60	Riffles
"	2	"	"	"	"	26.0	"		"	"	62,187	"	"	0.17776	237	"	"
"	3	"	"	"	"	25.6	"		"	"	61,691	"	"	0.18602	226	"	"
"	4	"	"	"	"	25.5	"		"	"	61,551	"	"	0.18602	217	"	"
"	5	"	"	"	"	25.5	"		"	"	61,551	"	"	0.25630	208	"	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 34
U. S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS
SYNTHETIC SANDS $U_{0.589}$, $U_{0.833}$, $U_{0.293}$ AND A.

Author's references							Velocity centimeters per second									
Test Number	Run Number	Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Mean V_m	Bottom V_b	Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, $G^{(2)}$ grams per second per centimeter	Duration of run minutes	Bed condition
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND $U_{0.589}$																
1	1	8,665	30.48	7.65	0.0010	18.6	37.16	No Observations	6.20	2.47	22,153	0.0133	230.4	0.01447	30	No Observations
	2	"	"	7.68	"	18.5	37.01		6.24	2.47	22,142	0.0135	230.9	0.01323	"	
	3	"	"	7.65	"	18.6	37.16		6.20	2.47	22,153	0.0133	230.4	0.01075	"	
	4	"	"	7.68	"	18.6	37.01		6.24	2.47	22,206	0.0135	230.9	0.01199	"	
	5	"	"	7.65	"	18.6	37.16		6.20	2.47	22,153	0.0133	230.4	0.01075	"	
2	1	23,418	"	14.97	"	20.0	51.34		10.33	3.18	52,876	0.0135	530.3	0.09260	"	
	3	"	"	16.92	"	20.0	45.42		12.58	3.51	56,967	0.0175	571.4	0.10583	"	
	4	"	"	17.43	"	20.1	44.07		13.14	3.59	57,850	0.0185	579.1	0.07937	"	
	5-6	"	"	17.59	"	20.3	43.69		13.35	3.62	58,560	0.0189	583.3	0.08599	"	
3	1	38,766	"	22.71	"	20.5	56.01		14.72	3.80	83,195	0.0157	824.5	0.12898	"	
	2	"	"	26.15	"	20.6	48.63		18.75	4.29	92,289	0.0214	911.8	0.09591	"	
	3	"	"	26.85	"	20.7	47.36		19.55	4.38	93,903	0.0225	925.9	0.09839	"	
	4	"	"	26.91	"	20.7	47.26		19.60	4.38	93,945	0.0226	926.3	0.05746	"	
	5	"	"	27.10	"	20.8	46.94		19.81	4.41	94,596	0.0229	929.9	0.07937	"	
SAND $U_{0.833}$																
4	1	8,665	30.48	7.56	0.0010	21.0	37.61	No Observations	6.10	2.45	23,458	0.0131	229.4	0.00579	30	No Observations
	2	"	"	7.59	"	21.0	37.46		6.13	2.45	23,480	0.0131	229.6	0.00537	"	
	3	"	"	7.59	"	21.0	37.46		6.13	2.45	23,480	0.0131	229.6	0.00579	"	
	4	"	"	7.62	"	21.0	37.31		6.17	2.46	23,538	0.0133	230.2	0.00579	"	
	5	"	"	7.62	"	21.0	37.31		6.17	2.46	23,538	0.0133	230.2	0.00744	"	
5	1	23,418	"	15.15	"	21.3	50.72		10.58	3.22	55,321	0.0140	536.6	0.05663	"	
	2	"	"	17.13	"	21.0	44.85		12.84	3.55	58,883	0.0180	575.9	0.02232	"	
	3	"	"	17.13	"	21.0	44.85		12.84	3.55	58,883	0.0180	575.9	0.02150	"	
	4	"	"	17.07	"	21.0	45.01		12.74	3.54	58,633	0.0177	573.4	0.04175	"	
	5	"	"	17.25	"	21.0	44.53		12.96	3.57	59,009	0.0182	577.1	0.04547	"	
	6-7	"	"	17.37	"	20.0	44.22		13.11	3.59	57,799	0.0185	579.7	0.07069	"	
6	1	38,766	"	22.52	"	20.0	56.46		14.53	3.78	81,791	0.0155	820.4	0.09632	"	
	2	"	"	26.00	"	20.0	48.92		18.58	4.27	90,621	0.0211	908.9	0.09632	"	
	3	"	"	26.76	"	20.0	47.52		19.41	4.36	91,960	0.0223	922.4	0.07317	"	
	4	"	"	27.07	"	19.8	46.99		19.78	4.40	92,209	0.0229	929.5	0.05994	"	
	5	"	"	26.88	"	19.9	47.31		20.08	4.44	94,432	0.0226	950.0	0.07317	"	
SAND $U_{0.293}$																
7	1	8,665	30.48	8.41	0.0010	20.5	33.79	No Observations	7.03	2.63	23,970	0.0159	237.5	0.00992	30	No Observations
	2	"	"	9.08	"	20.4	31.30		7.74	2.76	24,397	0.0183	242.3	0.00496	"	
	3	"	"	9.60	"	20.4	29.61		8.31	2.86	24,779	0.0204	246.1	0.00331	"	
	4	"	"	9.85	"	20.3	28.88		8.56	2.90	24,821	0.0212	247.2	0.00537	"	
	5	"	"	10.33	"	20.0	27.51		9.09	2.99	24,932	0.0233	250.1	0.00165	"	
8	2	23,418	"	16.73	"	20.2	45.92		12.35	3.48	56,768	0.0170	567.1	0.05291	"	
	3	"	"	17.16	"	20.2	44.77		12.86	3.56	57,856	0.0181	578.0	0.05250	"	
	4	"	"	17.28	"	20.2	44.46		13.00	3.57	57,856	0.0182	578.0	0.04341	"	
	5	"	"	17.34	"	20.2	44.30		13.07	3.58	57,958	0.0184	579.0	0.03059	"	
	6	"	"	17.37	"	20.2	44.22		13.09	3.58	57,942	0.0184	578.8	0.03679	"	
9	2	38,766	"	25.73	"	20.0	49.44		18.26	4.23	90,007	0.0206	902.8	0.03266	"	
	3	"	"	26.67	"	20.0	47.69		19.35	4.36	92,004	0.0223	922.8	0.01654	"	
	4	"	"	26.88	"	20.0	47.31		19.58	4.38	92,356	0.0225	926.3	0.02356	"	
	5	"	"	26.61	"	20.0	47.80		19.23	4.34	91,644	0.0220	919.2	0.02976	"	
	6	"	"	26.76	"	20.0	47.52		19.41	4.37	92,339	0.0223	926.2	0.03348	"	
SAND A																
10	1	8,665	30.48	7.50	0.0010	19.1	37.91	No Observations	6.04	2.43	22,296	0.0129	229.0	0.01170	30	No Observations
	2	"	"	7.47	"	19.0	38.07		6.00	2.43	22,155	0.0127	228.4	0.01166	"	
	3	"	"	7.41	"	19.0	38.38		5.93	2.41	22,075	0.0125	227.6	0.01162	"	
	4	"	"	7.41	"	19.0	38.38		5.93	2.41	22,075	0.0125	227.6	0.01182	"	
	5	"	"	7.50	"	19.0	37.91		6.04	2.43	22,209	0.0129	229.0	0.01753	"	
11	1	23,418	"	14.94	"	19.5	51.44		10.33	3.18	52,301	0.0135	531.4	0.08350	"	
	2	"	"	15.27	"	19.5	50.31		10.71	3.24	53,033	0.0142	538.8	0.09177	"	
	3	"	"	15.79	"	19.5	48.66		11.30	3.33	54,120	0.0151	549.9	0.15047	"	
	4	"	"	16.15	"	19.5	47.56		11.72	3.39	54,863	0.0159	557.4	0.14634	"	
	5	"	"	16.12	"	19.5	47.65		11.70	3.39	54,873	0.0159	557.5	0.14882	"	
	6	"	"	16.06	"	19.5	47.83		11.61	3.37	54,656	0.0157	555.3	0.04671	"	
	7	"	"	16.03	"	19.5	47.92		11.59	3.37	54,665	0.0157	555.4	0.15047	"	
	8	"	"	16.06	"	19.5	47.83		11.61	3.37	54,656	0.0157	555.3	0.04671	"	
12	1	38,766	"	23.07	"	19.2	55.12		15.15	3.85	81,629	0.0163	835.1	0.10707	"	
	2	"	"	25.79	"	19.2	49.32		18.31	4.24	88,275	0.0206	903.0	0.06366	"	

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 34 (CONTINUED)
U. S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS.
SYNTHETIC SANDS A, B, C, D AND E.

Author's references		Discharge, Q cubic centimeters per second (3)	Width of flume, B centimeters (4)	Mean water depth, D centimeters (5)	Water surface slope, S (6)	Water temperature degrees centigrade (7)	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters (10)	Friction velocity, V^* centimeters per second (11)	Reynolds Number, R (12)	Manning's n of bed, n_b (1) (13)	Unit discharge, q_b cubic centimeters per second per centimeter (14)	Rate of bed movement, G (2) grams per second per centimeter (15)	Duration of run minutes (16)	Bed condition (17)
Test Number (1)	Run Number (2)						Mean V_m (8)	Bottom V_b (9)								
SAND A -(CONTINUED)																
12	3	38,766	30.48	25.94	0.0010	19.2	49.03		18.49	4.26	88,618	0.0209	906.6	0.10376	30	
	4	"	"	26.12	"	19.2	48.69		18.66	4.28	88,813	0.0211	908.6	0.10045	"	
	5	"	"	26.18	"	19.2	48.58		18.77	4.29	89,135	0.0214	911.8	0.04299	"	
SAND B																
13	1	8,665	"	7.38	0.0010	19.5	38.54	No Observations	5.92	2.41	22,456	0.0126	228.2	0.00992	30	No Observations
	2	"	"	7.44	"	19.5	38.22		5.97	2.42	22,458	0.0127	228.2	0.01153	"	
	3	"	"	7.44	"	19.5	38.22		5.97	2.42	22,458	0.0127	228.2	0.00827	"	
	4	"	"	7.47	"	19.5	38.07		6.00	2.43	22,482	0.0127	228.4	0.01170	"	
	5	"	"	7.59	"	19.5	37.46		6.09	2.44	22,454	0.0129	228.1	0.01348	"	
14	1	23,418	"	14.97	"	19.5	51.34		10.37	3.19	52,401	0.0136	532.4	0.08226	"	
	2	"	"	16.52	"	19.5	46.51		12.12	3.45	55,482	0.0166	563.7	0.08020	"	
	3-4	"	"	16.92	"	19.2	45.42		12.58	3.51	55,854	0.0175	571.4	0.07222	"	
	5	"	"	16.98	"	19.2	45.25		12.63	3.52	55,866	0.0175	571.5	0.07400	"	
15	1	38,766	"	22.34	"	19.4	56.93		14.29	3.74	79,915	0.0151	813.5	0.12567	"	
	3	"	"	26.43	"	19.6	48.13		19.02	4.32	90,368	0.0217	915.4	0.11906	"	
	4-5	"	"	26.06	"	19.6	48.80		18.61	4.27	89,651	0.0211	908.2	0.10252	"	
	6	"	"	27.37	"	19.8	46.47		20.17	4.45	92,986	0.0234	937.3	0.05746	"	
	7	"	"	27.13	"	19.8	46.88		19.83	4.41	92,225	0.0229	929.6	0.09425	"	
SAND C																
16	1	8,665	"	7.41	0.0010	19.6	38.38	No Observations	5.93	2.41	22,467	0.0125	227.6	0.01984	30	No Observations
	2	"	"	7.35	"	19.6	38.70		5.87	2.40	22,425	0.0123	227.2	0.02232	"	
	3	"	"	7.41	"	20.0	38.38		5.93	2.41	22,691	0.0125	227.6	0.01860	"	
	4	"	"	7.41	"	20.0	38.38		5.93	2.41	22,691	0.0125	227.6	0.02811	"	
	5	"	"	7.41	"	20.0	38.38		5.93	2.41	22,691	0.0125	227.6	0.01199	"	
17	1	23,418	"	14.84	"	20.1	51.76		10.20	3.16	52,742	0.0133	528.0	0.08929	"	
	2	"	"	15.88	"	20.2	48.38		11.39	3.34	55,160	0.0153	551.0	0.10045	"	
	3	"	"	16.43	"	20.2	46.77		12.01	3.43	56,227	0.0164	561.7	0.16370	"	
	4	"	"	16.22	"	20.3	47.38		11.76	3.40	55,943	0.0160	557.2	0.11658	"	
	5	"	"	16.37	"	20.5	46.94		11.96	3.43	56,650	0.0163	561.4	0.08185	"	
18	1	38,766	"	22.22	"	20.6	57.24		14.15	3.73	81,978	0.0150	809.9	0.14179	"	
	3-4	"	"	26.33	"	20.6	48.30		18.88	4.30	92,298	0.0215	911.9	0.08330	"	
	6	"	"	26.64	"	20.4	47.74		19.25	4.35	92,547	0.0220	919.0	0.09591	"	
	7	"	"	26.33	"	20.4	48.30		18.88	4.30	91,833	0.0214	911.9	0.07441	"	
SAND D																
19	1	8,665	"	7.47	0.0010	20.8	38.07	No Observations	6.00	2.43	23,237	0.0127	228.4	0.00099	30	No Observations
	2	"	"	7.44	"	20.8	38.22		5.97	2.42	23,212	0.0127	228.2	0.00178	"	
	3	"	"	7.53	"	20.8	37.76		6.07	2.44	23,317	0.0129	229.2	0.00289	"	
	4	"	"	7.56	"	20.8	37.61		6.10	2.45	23,339	0.0131	229.4	0.00318	"	
	5	"	"	7.56	"	20.9	37.61		6.10	2.45	23,386	0.0131	229.4	0.00298	"	
20	1	23,418	"	15.39	"	21.0	49.91		10.84	3.26	55,319	0.0144	541.0	0.04105	"	
	2	"	"	15.39	"	21.0	49.91		10.84	3.26	55,319	0.0144	541.0	0.03278	"	
	3	"	"	15.42	"	21.0	49.82		10.86	3.26	55,322	0.0144	541.0	0.06453	"	
	4	"	"	15.61	"	21.0	49.23		11.08	3.30	55,774	0.0147	545.5	0.07441	"	
	5	"	"	15.97	"	21.0	48.10		11.50	3.36	56,559	0.0155	553.2	0.04737	"	
	6	"	"	16.28	"	20.8	47.20		11.85	3.41	56,899	0.0161	559.3	0.03270	"	
21	1	38,766	"	22.95	"	20.6	55.42		15.03	3.84	84,308	0.0161	833.0	0.07515	"	
	2	"	"	23.41	"	20.6	54.33		15.56	3.91	85,564	0.0169	845.4	0.07586	"	
	3	"	"	23.71	"	20.5	53.63		15.90	3.95	86,046	0.0173	852.7	0.08102	"	
	4	"	"	24.17	"	21.1	52.62		16.41	4.01	88,564	0.0180	863.5	0.10541	"	
	5	"	"	24.38	"	21.0	52.16		16.69	4.05	89,013	0.0184	870.6	0.08764	"	
SAND E																
22	1	8,665	"	7.53	0.0010	19.8	37.76	No Observations	6.07	2.44	22,738	0.0129	229.2	0.00860	30	No Observations
	2	"	"	7.56	"	19.8	37.61		6.10	2.45	22,760	0.0131	229.4	0.01021	"	
	3	"	"	7.59	"	19.8	37.46		6.13	2.45	22,781	0.0131	229.6	0.01360	"	
	4	"	"	7.56	"	19.7	37.61		6.10	2.45	22,692	0.0131	229.4	0.01021	"	
	5	"	"	7.56	"	19.7	37.61		6.10	2.45	22,692	0.0131	229.4	0.00508	"	
23	1	23,418	"	15.42	"	19.8	49.82		10.91	3.27	53,922	0.0146	543.5	0.05374	"	
	2	"	"	15.58	"	19.8	49.33		11.06	3.29	54,126	0.0147	545.6	0.07119	"	
	3	"	"	15.85	"	19.8	48.48		11.36	3.34	54,636	0.0153	550.7	0.06792	"	
	4	"	"	16.12	"	19.8	47.65		11.65	3.38	55,072	0.0158	555.1	0.06792	"	
	5	"	"	16.12	"	19.9	47.65		11.70	3.39	55,418	0.0159	557.5	0.03741	"	
24	1	38,766	"	22.28	"	19.8	57.08		14.59	3.78	82,619	0.0158	832.8	0.08474	"	
	2	"	"	22.77	"	19.8	55.86		14.82	3.81	82,128	0.0159	827.8	0.10541	"	

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry Weight.

TABLE 34 (CONTINUED)
U. S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS.
SYNTHETIC SANDS E, F, G, H AND I.

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V_* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
Test Number	Run Number						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND E-(CONTINUED)																
24	3	38,766	30.48	24.29	0.0010	19.6	52.36		16.56	4.03	85,595	0.0182	867.1	0.14613	30	
	4	〃	〃	25.42	〃	19.6	50.03		17.91	4.19	88,454	0.0201	896.0	0.05994	〃	
	5	〃	〃	25.85	〃	19.5	49.21		18.43	4.25	89,266	0.0209	906.9	0.10665	〃	
SAND F																
25	1	8,665	30.48	7.41	0.0010	19.9	38.38		5.95	2.42	22,700	0.0126	228.4	0.00496	30	
	2	〃	〃	7.50	〃	19.9	37.91		6.04	2.43	22,761	0.0129	229.0	0.00703	〃	
	3	〃	〃	7.47	〃	19.8	38.07		6.00	2.43	22,661	0.0127	228.4	0.00868	〃	
	4	〃	〃	7.53	〃	19.8	37.76		6.07	2.44	22,738	0.0129	229.2	0.00868	〃	
	5	〃	〃	7.53	〃	19.8	37.76	No Observations	6.07	2.44	22,738	0.0129	229.2	0.00868	〃	No Observations
26	1	23,418	〃	15.21	〃	19.6	50.51		10.63	3.23	53,003	0.0140	536.9	0.07193	〃	
	2	〃	〃	15.12	〃	19.8	50.82		10.52	3.21	53,038	0.0138	534.6	0.09549	〃	
	3	〃	〃	15.73	〃	19.8	48.85		11.23	3.32	54,423	0.0151	548.6	0.10583	〃	
	4	〃	〃	15.97	〃	19.8	48.10		11.50	3.36	54,876	0.0155	553.2	0.09219	〃	
	5	〃	〃	15.88	〃	19.8	48.38		11.39	3.34	54,667	0.0153	551.0	0.11410	〃	
27	1	38,766	〃	22.62	〃	19.9	56.24		14.62	3.79	81,732	0.0155	822.2	0.09921	〃	
	2	〃	〃	23.26	〃	19.9	54.69		15.43	3.89	83,883	0.0166	843.9	0.11286	〃	
	3	〃	〃	23.74	〃	19.9	53.57		15.96	3.96	84,988	0.0173	855.0	0.14345	〃	
	4	〃	〃	24.05	〃	19.9	52.89		16.26	3.99	85,486	0.0178	860.0	0.16040	〃	
	5	〃	〃	24.05	〃	20.0	52.89		16.40	4.01	86,480	0.0181	867.4	0.17280	〃	
SAND G																
28	1	8,665	30.48	7.50	0.0010	20.6	37.91		6.04	2.43	23,176	0.0129	229.0	0.00331	30	
	2	〃	〃	7.53	〃	20.6	37.76		6.07	2.44	23,199	0.0129	229.2	0.00992	〃	
	3	〃	〃	7.56	〃	20.6	37.61		6.10	2.45	23,221	0.0131	229.4	0.00909	〃	
	4	〃	〃	7.53	〃	20.6	37.76		6.07	2.44	23,199	0.0129	229.2	0.00744	〃	
	5	〃	〃	7.53	〃	20.6	37.76	No Observations	6.07	2.44	23,199	0.0129	229.2	0.00661	〃	No Observations
29	1	23,418	〃	15.21	〃	21.0	50.51		10.63	3.23	54,900	0.0140	536.9	0.05291	〃	
	2	〃	〃	15.24	〃	21.0	50.41		10.69	3.24	55,101	0.0141	538.9	0.06821	〃	
	3	〃	〃	16.28	〃	21.0	47.20		11.85	3.41	57,190	0.0162	559.3	0.05705	〃	
	4	〃	〃	16.40	〃	21.0	46.85		11.99	3.43	57,437	0.0164	561.7	0.07730	〃	
	5	〃	〃	16.34	〃	20.8	47.03		11.94	3.42	57,125	0.0163	561.5	0.06408	〃	
30	1	38,766	〃	22.52	〃	20.8	56.46		14.56	3.78	83,627	0.0155	822.1	0.09880	〃	
	2	〃	〃	23.38	〃	20.8	54.40		15.54	3.90	86,000	0.0168	845.4	0.13146	〃	
	3	〃	〃	23.93	〃	21.0	53.15		16.18	3.98	87,931	0.0177	860.0	0.20049	〃	
	4	〃	〃	24.29	〃	21.0	52.36		16.56	4.03	88,659	0.0182	867.1	0.17156	〃	
	5	〃	〃	23.99	〃	21.0	53.02		16.22	3.99	87,933	0.0177	860.0	0.05415	〃	
SAND H																
31	1	8,665	30.48	7.53	0.0010	21.1	37.76		6.07	2.44	23,508	0.0129	229.2	0.00703	30	
	2	〃	〃	7.53	〃	21.1	37.76		6.07	2.44	23,508	0.0129	229.2	0.00868	〃	
	3	〃	〃	7.53	〃	21.1	37.76		6.07	2.44	23,508	0.0129	229.2	0.00703	〃	
	4	〃	〃	7.53	〃	21.0	37.76		6.07	2.44	23,436	0.0129	229.2	0.00703	〃	
	5	〃	〃	7.53	〃	21.0	37.76	No Observations	6.07	2.44	23,436	0.0129	229.2	0.00496	〃	No Observations
32	1	23,418	〃	15.18	〃	21.0	50.62		10.60	3.22	54,864	0.0140	536.6	0.06904	〃	
	2	〃	〃	15.97	〃	20.8	48.10		11.50	3.36	56,272	0.0155	553.2	0.07854	〃	
	3	〃	〃	16.00	〃	20.8	48.01		11.52	3.36	56,264	0.0155	553.1	0.04754	〃	
	4	〃	〃	16.12	〃	20.8	47.65		11.70	3.39	56,715	0.0159	557.5	0.05663	〃	
	5	〃	〃	16.22	〃	21.0	47.38		11.81	3.40	57,214	0.0161	559.6	0.06780	〃	
33	1	38,766	〃	22.92	〃	21.0	55.49		15.01	3.84	85,164	0.0161	832.9	0.08888	〃	
	2	〃	〃	23.93	〃	21.0	53.15		16.21	3.99	88,094	0.0177	861.6	0.10996	〃	
	3	〃	〃	24.99	〃	21.0	50.89		17.39	4.13	90,488	0.0193	885.0	0.14345	〃	
	4	〃	〃	24.99	〃	21.0	50.89		17.39	4.13	90,488	0.0193	885.0	0.16742	〃	
	5	〃	〃	24.44	〃	21.0	52.03		16.77	4.06	89,217	0.0185	872.5	0.05787	〃	
SAND I																
34	1	8,665	30.48	7.50	0.0010	21.0	37.91		6.04	2.43	23,413	0.0129	229.0	0.00331	30	
	2	〃	〃	7.53	〃	21.0	37.76		6.07	2.44	23,436	0.0129	229.2	0.00496	〃	
	3	〃	〃	7.56	〃	21.0	37.61	No Observations	6.09	2.44	23,420	0.0130	229.0	0.00868	〃	No Observations
	4	〃	〃	7.53	〃	21.0	37.76		6.07	2.44	23,436	0.0129	229.2	0.00868	〃	
	5	〃	〃	7.53	〃	21.0	37.76		6.07	2.44	23,436	0.0129	229.2	0.00703	〃	
35	1	23,418	〃	15.24	〃	20.9	50.41		10.69	3.24	54,932	0.0141	538.9	0.06904	〃	
	2	〃	〃	15.36	〃	20.9	50.01		10.82	3.26	55,159	0.0143	541.1	0.07813	〃	
	3	〃	〃	15.33	〃	20.9	50.11		10.80	3.25	55,167	0.0143	541.2	0.09921	〃	
	4	〃	〃	15.82	〃	21.0	48.57		11.34	3.34	56,317	0.0153	550.8	0.05829	〃	
	5	〃	〃	15.97	〃	21.0	48.10		11.50	3.36	56,559	0.0155	553.2	0.08557	〃	

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 34 (CONTINUED)
U. S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS
SYNTHETIC SANDS I, $U_{0.417}$, J, K AND L

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
Test Number	Run Number						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND I - (CONTINUED)																
36	1	38,766	30.48	22.52	0.0010	21.0	56.46		14.53	3.78	83,882	0.0155	820.4	0.09591	30	
	2	"	"	23.01	"	21.0	55.27		15.14	3.85	85,561	0.0163	836.8	0.09921	"	
	3	"	"	23.93	"	21.0	53.15		16.18	3.98	87,931	0.0177	860.0	0.16081	"	
	4	"	"	24.75	"	21.0	51.39		17.15	4.10	90,116	0.0191	881.3	0.16081	"	
	5	"	"	24.48	"	21.0	51.97		16.82	4.06	89,380	0.0186	874.1	0.10996	"	
SAND $U_{0.417}$																
37	1	8,665	30.48	7.41	0.0010	21.6	38.38	No Observations	5.93	2.41	23,609	0.0125	227.6	0.02026	30	No Observations
	2	"	"	7.47	"	21.6	38.07		6.00	2.43	23,695	0.0127	228.4	0.02687	"	
	3	"	"	7.53	"	21.6	37.76		6.07	2.44	23,776	0.0129	229.2	0.02191	"	
	4	"	"	7.65	"	21.6	37.16		6.20	2.47	23,900	0.0133	230.4	0.02356	"	
	5	"	"	7.83	"	22.0	36.29		6.40	2.51	23,342	0.0139	232.3	0.02274	"	
38	1	23,418	"	15.18	"	21.9	50.62		10.60	3.22	56,068	0.0140	536.6	0.06697	"	
	2	"	"	16.28	"	21.9	47.20		11.85	3.41	58,445	0.0161	559.3	0.08350	"	
	3	"	"	16.34	"	21.9	47.03		11.94	3.42	58,677	0.0163	561.5	0.06366	"	
	4	"	"	16.52	"	21.9	46.51		12.12	3.45	58,903	0.0166	563.7	0.05705	"	
	5	"	"	16.40	"	21.9	46.85		11.99	3.43	58,697	0.0164	561.7	0.05663	"	
39	1	38,766	"	22.80	"	22.1	55.78		14.84	3.82	86,860	0.0159	827.8	0.08723	"	
	2	"	"	24.41	"	22.3	52.09		16.75	4.05	92,037	0.0184	872.5	0.13725	"	
	3	"	"	25.69	"	22.3	49.50		18.24	4.23	95,241	0.0206	902.9	0.11368	"	
	4	"	"	25.69	"	22.4	49.50		18.24	4.23	95,543	0.0206	902.9	0.08020	"	
	5	"	"	25.51	"	22.3	49.85		17.97	4.20	94,494	0.0201	895.8	0.04671	"	
SAND J																
40	1	8,665	30.48	7.56	0.0010	22.3	37.61	No Observations	6.10	2.45	24,201	0.0131	229.4	0.00703	30	No Observations
	2	"	"	7.65	"	22.2	37.16		6.20	2.47	24,252	0.0133	230.4	0.01033	"	
	3	"	"	7.65	"	22.6	37.16		6.20	2.47	24,510	0.0133	230.4	0.01323	"	
	4	"	"	7.62	"	22.6	37.31		6.17	2.46	24,490	0.0133	230.2	0.01033	"	
	5	"	"	7.62	"	22.6	37.31		6.17	2.46	24,490	0.0133	230.2	0.00868	"	
41	1	23,418	"	15.09	"	22.6	50.92		10.50	3.21	56,879	0.0138	534.7	0.05787	"	
	2	"	"	15.30	"	22.6	50.21		10.74	3.25	57,368	0.0142	539.3	0.07896	"	
	3	"	"	15.54	"	22.7	49.43		11.02	3.29	58,072	0.0147	544.7	0.05994	"	
	4	"	"	15.39	"	22.8	49.91		10.84	3.26	57,864	0.0144	541.0	0.07028	"	
	5	"	"	15.48	"	22.8	49.62		10.95	3.28	58,111	0.0146	543.3	0.04961	"	
42	1	38,766	"	22.95	"	22.8	55.42		15.00	3.84	88,909	0.0161	831.3	0.10624	"	
	2	"	"	23.07	"	22.8	55.12		15.18	3.86	89,489	0.0163	836.7	0.13725	"	
	3	"	"	23.56	"	22.5	53.98		15.77	3.93	90,272	0.0171	851.3	0.09095	"	
	4	"	"	23.93	"	22.5	53.15		16.28	4.00	91,758	0.0179	865.3	0.13890	"	
	5	"	"	24.81	"	22.4	51.26		17.19	4.11	93,244	0.0191	881.2	0.14221	"	
SAND K																
43	1	8,665	30.48	7.62	0.0010	22.5	37.31	No Observations	6.17	2.46	24,412	0.0133	230.2	0.01654	30	No Observations
	2	"	"	7.65	"	22.5	37.16		6.20	2.47	24,432	0.0133	230.4	0.01984	"	
	3	"	"	7.71	"	22.5	36.87		6.27	2.48	24,515	0.0135	231.2	0.01819	"	
	4	"	"	7.71	"	22.6	36.87		6.27	2.48	24,593	0.0135	231.2	0.03100	"	
	5	"	"	7.68	"	22.6	37.01		6.24	2.47	24,568	0.0135	230.9	0.02150	"	
44	1	23,418	"	15.06	"	22.6	51.03		10.43	3.20	56,622	0.0137	532.2	0.10665	"	
	2	"	"	16.40	"	22.6	46.85		11.99	3.43	59,759	0.0164	561.7	0.10169	"	
	3	"	"	17.01	"	20.8	45.17		12.70	3.53	58,358	0.0177	573.7	0.10831	"	
	4	"	"	17.25	"	20.8	44.53		12.95	3.56	58,664	0.0182	576.7	0.06780	"	
	5	"	"	17.43	"	20.8	44.07		13.14	3.59	58,909	0.0185	579.1	0.10831	"	
45	1	38,766	"	22.74	"	20.8	55.93		14.80	3.81	84,208	0.0159	827.8	0.10707	"	
	2	"	"	23.68	"	20.9	53.70		15.88	3.95	86,927	0.0173	852.8	0.13807	"	
	3	"	"	25.51	"	20.8	49.85		18.04	4.21	91,485	0.0203	899.3	0.07358	"	
	4	"	"	26.40	"	20.8	48.18		19.00	4.32	93,125	0.0217	915.4	0.09715	"	
	5	"	"	26.43	"	20.8	48.13		19.02	4.32	93,126	0.0217	915.4	0.14634	"	
SAND L																
46	1	8,665	30.48	7.47	0.0010	21.2	38.07	No Observations	6.00	2.43	23,500	0.0127	228.4	0.01695	30	No Observations
	2	"	"	7.47	"	21.2	38.07		6.00	2.43	23,500	0.0127	228.4	0.01695	"	
	3	"	"	7.44	"	21.2	38.22		5.97	2.42	23,475	0.0127	228.2	0.02067	"	
	4	"	"	7.44	"	21.2	38.22		5.97	2.42	23,475	0.0127	228.2	0.01695	"	
	5	"	"	7.47	"	21.2	38.07		6.00	2.43	23,500	0.0127	228.4	0.01530	"	
47	1	23,418	"	14.72	"	21.5	52.19		10.08	3.14	54,459	0.0131	526.1	0.10583	"	
	2	"	"	15.88	"	21.5	48.38		11.39	3.34	57,044	0.0153	551.0	0.10665	"	
	3	"	"	16.34	"	21.5	47.03		11.94	3.42	58,130	0.0163	561.5	0.11575	"	
	4	"	"	16.28	"	21.6	47.20		11.85	3.41	58,021	0.0161	559.3	0.10583	"	

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 34 (CONTINUED)
U. S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS.
SYNTHETIC SANDS L, M, J, E AND FITLER.

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
Test Number	Run Number						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND L -(CONTINUED)																
47	5	23,418	30.48	16.37	0.0010	21.6	46.94		11.96	3.43	58,237	0.0163	561.4	0.11575	30	
48	1	38,766	"	22.52	"	21.5	56.46		14.53	3.78	84,924	0.0155	820.4	0.11079	"	
	2	"	"	24.14	"	21.5	52.68		16.43	4.01	89,600	0.0180	865.5	0.12278	"	
	3	"	"	25.82	"	21.5	49.26		18.33	4.24	93,472	0.0207	902.9	0.11079	"	
	4	"	"	28.13	"	21.5	45.21		21.00	4.54	98,283	0.0247	949.4	0.12608	"	
SAND M																
49	1	8,665	30.48	7.50	0.0010	21.5	37.91	No Observations	6.04	2.43	23,704	0.0129	229.0	0.01571	30	No Observations
	2	"	"	7.50	"	21.5	37.91		6.04	2.43	23,704	0.0129	229.0	0.02191	"	
	3	"	"	7.53	"	21.6	37.76		6.07	2.44	23,776	0.0129	229.2	0.01860	"	
	4	"	"	7.71	"	21.6	36.87		6.27	2.48	23,981	0.0135	231.2	0.01488	"	
	5	"	"	7.68	"	21.6	37.01		6.24	2.47	23,957	0.0135	230.9	0.01571	"	
50	1	23,418	"	15.06	"	21.6	51.03		10.43	3.20	55,212	0.0136	532.2	0.07896	"	
	2	"	"	16.76	"	21.6	45.83		12.47	3.50	59,284	0.0174	571.5	0.08557	"	
	3	"	"	17.56	"	21.7	43.76		13.28	3.61	60,409	0.0188	581.1	0.12608	"	
	4	"	"	16.98	"	21.6	45.25		12.77	3.54	59,942	0.0180	577.8	0.14055	"	
51	1	38,766	"	22.65	"	21.8	56.16		14.71	3.80	86,143	0.0157	826.1	0.10500	"	
	2	"	"	24.29	"	21.8	52.36		16.56	4.03	90,415	0.0182	867.1	0.11368	"	
	3	"	"	26.03	"	21.9	48.86		18.63	4.27	95,116	0.0211	910.3	0.11079	"	
	4	"	"	26.33	"	21.9	48.30		18.96	4.31	95,692	0.0217	915.8	0.13394	"	
	5	"	"	26.76	"	21.9	47.52		19.41	4.36	96,381	0.0223	922.4	0.15378	"	
SAND J (REPEAT TEST)																
52	1	8,665	30.48	7.50	0.0010	22.4	37.91	No Observations	6.04	2.43	24,230	0.0129	229.0	0.00827	30	No Observations
	2	"	"	7.56	"	22.4	37.61		6.10	2.45	24,277	0.0131	229.4	0.00868	"	
	3	"	"	7.53	"	22.4	37.76		6.07	2.44	24,254	0.0129	229.2	0.00868	"	
	4	"	"	7.53	"	22.4	37.76		6.07	2.44	24,254	0.0129	229.2	0.00703	"	
	5	"	"	7.53	"	22.4	37.76		6.07	2.44	24,254	0.0129	229.2	0.00537	"	
53	1	23,418	"	15.27	"	22.4	50.31		10.71	3.24	57,018	0.0142	538.8	0.07441	"	
	2	"	"	15.54	"	22.4	49.43		11.02	3.29	57,642	0.0147	544.7	0.06490	"	
	3	"	"	15.76	"	22.4	48.76		11.28	3.33	58,202	0.0151	550.0	0.08185	"	
	5	"	"	15.91	"	22.2	48.29		11.41	3.35	57,999	0.0153	551.0	0.06160	"	
54	1	38,766	"	22.68	"	22.2	56.09		14.69	3.80	86,733	0.0157	824.0	0.11244	"	
	2	"	"	23.26	"	22.2	54.69		15.40	3.89	88,655	0.0166	842.2	0.15089	"	
	3	"	"	23.74	"	22.2	53.57		15.92	3.95	89,772	0.0173	852.8	0.11616	"	
	4	"	"	23.68	"	22.2	53.70		15.88	3.95	89,764	0.0173	852.8	0.15378	"	
	5	"	"	24.78	"	22.3	51.33		17.17	4.10	92,968	0.0191	881.3	0.11244	"	
SAND E (REPEAT TEST)																
55	1	8,665	30.48	7.59	0.0010	22.3	37.46	No Observations	6.13	2.45	24,223	0.0131	229.6	0.00785	30	No Observations
	2	"	"	7.62	"	22.0	37.31		6.17	2.46	24,105	0.0133	230.2	0.00827	"	
	3	"	"	7.59	"	22.0	37.46		6.13	2.45	24,045	0.0131	229.6	0.00909	"	
	4	"	"	7.59	"	22.0	37.46		6.13	2.45	24,045	0.0131	229.6	0.00661	"	
	5	"	"	7.59	"	22.0	37.46		6.13	2.45	24,045	0.0131	229.6	0.00496	"	
56	1	23,418	"	15.27	"	22.0	50.31		10.71	3.24	56,421	0.0142	538.8	0.04837	"	
	2	"	"	15.67	"	22.2	49.04		11.17	3.31	57,661	0.0149	547.8	0.08102	"	
	3	"	"	15.82	"	22.2	48.57		11.34	3.34	57,977	0.0153	550.8	0.05043	"	
	4	"	"	16.00	"	22.2	48.01		11.52	3.36	58,218	0.0155	553.1	0.08102	"	
	5	"	"	16.40	"	22.2	46.85		11.99	3.43	59,130	0.0164	561.7	0.04382	"	
57	1	38,766	"	22.71	"	22.4	56.01		14.78	3.81	87,601	0.0158	827.8	0.08764	"	
	2	"	"	22.92	"	22.4	55.49		14.98	3.83	87,962	0.0161	831.2	0.12154	"	
	3	"	"	24.29	"	22.4	52.36		16.63	4.04	92,143	0.0183	870.7	0.14179	"	
	4	"	"	25.88	"	22.4	49.15		18.45	4.25	95,960	0.0209	906.8	0.05746	"	
	5	"	"	26.06	"	22.4	48.80		18.65	4.28	96,309	0.0212	910.1	0.07441	"	
FITLER SAND																
58	1	8,665	30.48	7.44	0.0010	23.5	38.22	No Observations	5.96	2.42	24,760	0.0126	227.8	0.01571	30	No Observations
	2	"	"	7.35	"	23.5	38.70		5.87	2.40	24,692	0.0123	227.2	0.01695	"	
	3	"	"	7.41	"	23.5	38.38		5.93	2.41	24,738	0.0125	227.6	0.01943	"	
	4	"	"	7.35	"	23.5	38.70		5.87	2.40	24,692	0.0123	227.2	0.01943	"	
	5	"	"	7.32	"	23.5	38.86		5.82	2.39	24,583	0.0122	226.2	0.01902	"	
59	1	23,418	"	15.18	"	23.8	50.62		10.60	3.22	58,706	0.0140	536.6	0.07069	"	
	2	"	"	15.33	"	23.8	50.11		10.76	3.25	58,992	0.0142	539.2	0.13104	"	
	3	"	"	16.18	"	23.8	47.47		11.74	3.39	60,974	0.0159	557.3	0.10831	"	
	4	"	"	15.94	"	24.0	48.20		11.48	3.36	60,806	0.0155	553.3	0.10583	"	
	5	"	"	15.76	"	24.0	48.76		11.28	3.33	60,441	0.0151	550.0	0.07069	"	

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 34 (CONTINUED)

U. S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS.

FITLER SAND AND SAND H.

Author's references: Test Number (1)	Author's references: Run Number (2)	Discharge, Q cubic centimeters per second (3)	Width of flume, B centimeters (4)	Mean water depth, D centimeters (5)	Water surface slope, S (6)	Water temperature degrees centigrade (7)	Velocity centimeters per second: Mean V_m (8)	Velocity centimeters per second: Bottom V_b (9)	Hydraulic radius of bed, r_b centimeters (10)	Friction velocity, V^* centimeters per second (11)	Reynolds Number, R (12)	Manning's n of bed, n_b [(1)] (13)	Unit discharge, q_b cubic centimeters per second per centimeter (14)	Rate of bed movement, G [(2)] grams per second per centimeter (15)	Duration of run minutes (16)	Bed condition (17)
FITLER SAND- (CONTINUED)																
60	1	38,766	30.48	22.34	0.0010	24.0	56.93		14.29	3.74	89,399	0.0151	813.5	0.09012	30	
	2	"	"	23.71	"	24.0	53.63		15.93	3.95	93,882	0.0173	854.3	0.15337	"	
	3	"	"	25.24	"	24.2	50.40		17.71	4.17	98,737	0.0198	892.6	0.16701	"	
	4	"	"	25.66	"	24.4	49.56		18.22	4.23	100,331	0.0206	903.0	0.15213	"	
SAND H (REPEAT TEST)																
61	1	8,665	30.48	7.59	0.0010	24.3	37.46	No Observations	6.13	2.45	25,458	0.0131	229.6	0.00537	30	No Observations
	2	"	"	7.62	"	24.3	37.31		6.15	2.46	25,439	0.0131	229.5	0.01157	"	
	3	"	"	7.65	"	24.3	37.16		6.20	2.47	25,542	0.0133	230.4	0.01033	"	
	4	"	"	7.71	"	24.4	36.87		6.27	2.48	25,686	0.0135	231.2	0.01943	"	
	5	"	"	7.71	"	24.4	36.87		6.27	2.48	25,686	0.0135	231.2	0.01943	"	
62	1	23,418	"	15.33	"	24.3	50.11		10.80	3.25	59,999	0.0143	541.2	0.06118	"	
	2	"	"	15.94	"	24.3	48.20		11.48	3.36	61,345	0.0155	553.3	0.06821	"	
	3	"	"	16.31	"	24.3	47.12		11.88	3.41	62,060	0.0161	559.8	0.09301	"	
	4	"	"	16.22	"	24.3	47.38		11.76	3.40	61,773	0.0160	557.2	0.07854	"	
	5	"	"	16.25	"	24.5	47.29		11.78	3.40	61,966	0.0160	557.1	0.07854	"	
63	1	38,766	"	22.74	"	24.5	55.93		14.73	3.80	91,641	0.0157	823.8	0.11244	"	
	2	"	"	23.77	"	24.6	53.50		16.01	3.96	95,383	0.0175	856.5	0.10583	"	
	3	"	"	24.66	"	24.6	51.58		17.02	4.09	97,761	0.0188	877.9	0.13270	"	
	4	"	"	24.60	"	24.6	51.71		16.91	4.07	97,374	0.0186	874.4	0.13890	"	
	5	"	"	24.93	"	24.6	51.01		17.35	4.13	98,555	0.0193	885.0	0.10541	"	

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 35
U. S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS.
LIGHT-WEIGHT MATERIALS H1 AND H2

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
Table	Run Number						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
MATERIALS H1																
15	8	8,042	30.48	9.36	0.0005	29.5	28.19		7.41	1.91	25,758	0.0140	208.9	0.00318	65	Local scours
"	9	9,826	"	10.64	"	29.7	30.30		8.14	2.00	30,482	0.0139	246.6	0.00525	75	"
"	11	14,470	"	13.78	"	30.0	34.47		9.85	2.20	42,279	0.0138	339.5	0.01381	59	"
"	12	16,820	"	15.12	"	30.0	36.52		10.42	2.26	47,385	0.0135	380.5	0.01711	80	Waves
"	13	19,482	"	16.73	"	29.4	38.19		11.16	2.34	52,423	0.0136	426.2	0.03782	115	"
"	14	22,172	"	18.38	"	29.5	39.59		11.95	2.42	58,335	0.0137	473.1	0.05746	87	"
"	15	24,721	"	19.72	"	29.5	41.12		12.37	2.47	62,725	0.0135	508.7	0.08681	59	"
"	16	27,326	"	21.15	"	29.5	42.37		12.95	2.52	67,657	0.0135	548.7	0.12195	51	"
16	6	4,786	"	5.39	0.0010	29.3	29.11		4.69	2.15	16,769	0.0141	136.5	0.00141	45	Smooth
"	7	6,286	"	6.43	"	29.2	32.06	No Observations	5.46	2.31	21,446	0.0142	175.0	0.01472	45	Scours
"	8	8,240	"	7.56	"	27.6	35.75		6.22	2.47	27,457	0.0139	222.4	0.03534	60	Waves
"	9	10,704	"	9.17	"	27.7	38.28		7.35	2.69	34,784	0.0145	281.4	0.06614	82	"
"	10	12,884	"	10.42	"	27.8	40.54		8.17	2.83	40,990	0.0147	331.2	0.08598	60	"
"	11	15,716	"	11.92	"	27.8	43.25		9.08	2.98	48,601	0.0148	392.7	0.15708	70	"
"	12	18,661	"	13.53	"	27.0	45.23		10.09	3.15	53,568	0.0151	456.4	0.21661	59	"
"	13	20,954	"	15.24	"	26.9	45.11		11.37	3.34	60,129	0.0164	512.9	0.25009	62	"
"	14	25,768	"	16.70	"	26.8	50.60		11.67	3.38	69,064	0.0149	590.5	0.33938	57	"
17	5	3,440	"	3.90	0.0015	25.2	28.93		3.54	2.28	11,571	0.0144	102.4	0.00256	60	Scours
"	6	4,644	"	4.79	"	26.6	31.82		4.27	2.51	15,802	0.0149	135.9	0.02360	72	Waves
"	7	6,088	"	5.61	"	26.5	35.60		4.88	2.68	20,151	0.0145	173.7	0.06300	60	"
"	8	7,561	"	6.55	"	26.6	37.86		5.61	2.87	24,698	0.0150	212.4	0.08119	56	"
"	9	9,090	"	7.44	"	26.6	40.11		6.28	3.04	29,291	0.0153	251.9	0.11823	83	"
"	10	10,704	"	8.26	"	25.6	42.52		6.86	3.18	33,223	0.0153	291.7	0.15212	53	"
"	11	12,205	"	9.11	"	25.7	43.92		7.47	3.32	37,454	0.0156	328.1	0.18147	74	"
"	12	14,130	"	10.09	"	25.8	45.96		8.14	3.46	42,754	0.0158	374.1	0.25299	89	"
"	13	15,942	"	11.13	"	26.0	47.00		8.93	3.63	48,186	0.0165	419.7	0.34352	64	"
MATERIALS H2																
18	9	7,476	30.48	8.81	0.0005	25.5	27.83		6.98	1.85	22,080	0.0136	194.3	0.00037	65	Scours
"	10	9,090	"	10.00	"	25.5	29.84		7.71	1.95	26,148	0.0136	230.1	0.00186	53	"
"	11	10,760	"	11.13	"	25.5	31.73		8.32	2.02	30,000	0.0134	264.0	0.00384	57	"
"	12	12,573	"	12.34	"	25.5	33.41		8.99	2.10	34,136	0.0134	300.4	0.00951	61	Waves
"	13	15,234	"	13.99	"	25.5	35.72		9.78	2.19	39,693	0.0133	349.3	0.02832	57	"
"	14	17,641	"	15.54	"	25.5	37.25		10.64	2.29	45,034	0.0135	396.3	0.03902	49	"
"	15	20,133	"	17.07	"	24.3	38.71		11.31	2.36	48,537	0.0135	437.8	0.10252	89	"
"	16	22,965	"	18.56	"	24.3	40.60		11.80	2.41	53,115	0.0133	479.1	0.10045	102	"
"	17	25,485	"	19.69	"	23.0	42.46		11.98	2.42	54,699	0.0128	508.7	0.09487	72	"
"	18	28,232	"	21.09	"	23.0	43.92		12.44	2.47	58,753	0.0127	546.4	0.14510	68	"
"	19	31,064	"	22.49	"	22.9	45.29		12.86	2.51	62,422	0.0126	582.4	0.15543	72	"
"	20	34,037	"	23.56	"	23.0	47.40		12.71	2.50	64,785	0.0119	602.5	0.13145	60	"
"	21	34,037	"	23.87	"	22.5	46.79		13.14	2.54	65,265	0.0123	614.8	0.20008	44	"
19	5	2,611	"	3.69	0.0010	25.4	23.23	No Observations	3.35	1.81	8,821	0.0141	77.8	0.00012	60	Smooth
"	6	3,557	"	4.42	"	25.7	26.40		3.90	1.96	11,758	0.0138	103.0	0.00074	69	Scours
"	7	4,502	"	5.18	"	25.7	28.50		4.51	2.10	14,669	0.0146	128.5	0.00525	60	"
"	8	5,607	"	5.91	"	25.8	31.12		5.06	2.23	18,000	0.0139	157.5	0.01782	60	Waves
"	9	6,938	"	6.83	"	25.4	33.35		5.73	2.37	21,667	0.0141	191.1	0.03555	60	"
"	10	8,184	"	7.56	"	25.5	35.51		6.22	2.47	25,102	0.0140	220.9	0.04708	60	"
"	11	9,599	"	8.38	"	25.5	37.58		6.77	2.58	28,909	0.0140	254.4	0.08123	89	"
"	12	11,298	"	9.36	"	25.7	39.62		7.41	2.70	33,516	0.0141	293.6	0.09446	60	"
"	13	12,941	"	10.33	"	25.7	41.09		8.05	2.81	37,763	0.0144	330.8	0.13394	76	"
"	14	14,810	"	11.46	"	25.6	42.40		8.81	2.94	42,540	0.0148	373.5	0.18974	53	"
"	15	17,132	"	12.83	"	25.5	43.80		9.72	3.09	48,375	0.0153	425.7	0.20256	67	"
20	5	2,993	"	3.54	0.0015	25.9	27.77		3.23	2.18	10,275	0.0142	89.7	0.01343	65	Smooth
"	6	4,106	"	4.15	"	26.0	32.49		3.66	2.32	13,651	0.0131	118.9	0.03762	62	Waves
"	7	5,522	"	5.00	"	26.0	36.24		4.33	2.52	18,014	0.0132	156.9	0.06614	40	"
"	8	7,249	"	6.07	"	26.0	39.20		5.15	2.75	23,180	0.0137	201.9	0.09342	64	"
"	9	8,778	"	6.89	"	25.4	41.82		5.73	2.90	27,166	0.0138	239.6	0.15750	73	"
"	10	10,704	"	7.99	"	25.5	43.98		6.55	3.10	32,739	0.0143	288.1	0.20669	84	"
"	11	12,261	"	8.81	"	25.7	45.66		7.13	3.24	37,169	0.0146	325.6	0.24803	39	"
"	12	14,187	"	9.85	"	26.0	47.27		7.86	3.40	42,652	0.0150	371.5	0.34145	31	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight

TABLE 35 (CONTINUED)

U. S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS

LIGHT-WEIGHT MATERIALS H3, C1 AND C2

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
Table	Run Number						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
MATERIAL H3																
21	4	4,927	30.48	6.46	0.0005	15.0	25.02		5.33	1.62	11,681	0.0127	133.4	0.00157	45	Smooth
"	5	8,637	"	9.17	"	14.9	30.88		6.95	1.85	18,726	0.0122	214.6	0.00938	50	"
"	6	11,044	"	10.97	"	15.7	33.01		8.05	1.99	23,639	0.0126	265.7	0.01658	61	Waves
"	7	13,082	"	12.53	"	15.7	34.26		8.96	2.10	27,313	0.0131	307.0	0.02331	62	"
"	8	15,942	"	14.20	"	15.8	36.82		9.72	2.19	31,953	0.0128	357.9	0.04961	45	"
"	9	18,972	"	16.34	"	16.0	38.10		10.91	2.32	37,283	0.0134	415.7	0.06159	62	"
"	10	21,662	"	17.83	"	16.0	39.87		11.52	2.38	41,193	0.0133	459.3	0.07193	58	"
"	11	24,636	"	19.48	"	19.3	41.51		12.16	2.44	49,490	0.0132	504.8	0.08061	60	"
"	12	28,034	"	21.12	"	19.6	43.56		12.56	2.48	54,008	0.0129	547.1	0.12236	30	"
22	4	2,775	"	3.78	0.0010	20.9	24.08		3.41	1.83	8,378	0.0138	82.1	0.00107	65	Smooth
"	5	4,191	"	4.88	"	20.9	28.19		4.27	2.05	12,286	0.0137	120.4	0.00492	67	"
"	6	5,154	"	5.58	"	21.0	30.33	No Observations	4.79	2.17	14,857	0.0137	145.3	0.00963	60	"
"	7	6,456	"	6.49	"	21.0	32.61		5.49	2.32	18,303	0.0140	179.0	0.02683	50	Waves
"	8	7,844	"	7.35	"	21.0	35.02		6.07	2.44	21,738	0.0139	212.6	0.04465	60	"
"	9	9,401	"	8.26	"	21.0	37.34		6.68	2.56	25,501	0.0139	249.4	0.05870	54	"
"	10	11,412	"	9.48	"	21.0	39.50		7.50	2.71	30,297	0.0125	296.3	0.09921	57	"
"	11	13,082	"	10.55	"	20.9	40.69		8.26	2.85	34,296	0.0147	336.1	0.12732	57	"
"	12	15,150	"	11.70	"	21.0	42.46		8.99	2.97	39,029	0.0149	381.7	0.13766	61	"
"	13	17,896	"	13.20	"	21.0	44.50		9.91	3.12	45,092	0.0152	441.0	0.15998	47	"
"	14	20,870	"	14.51	"	21.0	47.18		10.58	3.22	51,043	0.0150	499.2	0.22901	36	"
23	4	2,180	"	2.99	0.0015	22.0	23.96		2.77	2.02	6,953	0.0148	66.4	0.00198	68	Smooth
"	5	2,973	"	3.51	"	22.1	27.83		3.20	2.17	9,349	0.0141	89.1	0.00674	70	"
"	6	3,908	"	4.15	"	22.2	30.94		3.72	2.34	12,116	0.0140	115.1	0.02336	65	Waves
"	7	5,239	"	5.06	"	22.3	33.95		4.45	2.56	15,956	0.0143	151.1	0.05043	63	"
"	8	6,570	"	5.91	"	22.3	36.45		5.12	2.75	19,704	0.0147	186.6	0.07813	60	"
"	9	8,070	"	6.77	"	22.6	39.14		5.76	2.91	23,979	0.0147	225.4	0.11616	56	"
"	10	9,769	"	7.71	"	22.4	41.57		6.46	3.08	28,413	0.0150	268.5	0.15874	45	"
"	11	11,836	"	8.75	"	22.4	44.38		7.16	3.25	33,630	0.0151	317.8	0.21289	45	"
"	12	13,847	"	9.75	"	22.6	46.57		7.83	3.40	38,787	0.0152	364.6	0.32657	22	"
MATERIAL C1																
24	9	12,516	30.48	12.53	0.0005	25.6	32.77		9.20	2.12	34,339	0.0139	301.5	0.00368	50	Smooth
"	10	14,810	"	13.75	"	25.8	35.36		9.69	2.18	39,154	0.0134	342.6	0.00236	60	Waves
"	11	17,188	"	15.45	"	25.7	36.48		10.67	2.29	44,429	0.0138	389.2	0.02712	60	"
"	12	19,539	"	16.86	"	25.7	38.04		11.31	2.36	49,110	0.0137	430.2	0.05696	60	"
"	13	22,342	"	18.23	"	25.7	40.20	No Observations	11.67	2.39	53,550	0.0133	469.1	0.06945	62	"
"	14	25,485	"	19.81	"	25.8	42.21		12.16	2.44	58,663	0.0130	513.3	0.10541	49	"
"	15	28,742	"	21.43	"	25.8	44.01		12.59	2.49	63,326	0.0128	554.1	0.12484	51	"
"	16	32,593	"	23.50	"	26.1	45.51		13.29	2.55	69,517	0.0128	604.8	0.23067	48	"
25	7	8,382	"	8.29	0.0010	26.9	33.16		6.95	2.61	27,022	0.0161	230.5	0.02794	39	"
"	8	10,477	"	9.60	"	26.9	35.81		7.86	2.78	33,002	0.0162	281.5	0.06784	66	"
"	9	12,686	"	10.94	"	26.7	38.04		8.81	2.94	39,102	0.0165	335.1	0.11761	48	"
"	10	15,093	"	12.31	"	26.6	40.20		9.69	3.08	45,291	0.0166	389.5	0.14902	55	"
"	11	17,585	"	13.47	"	26.6	42.82		10.30	3.18	51,279	0.0163	441.0	0.20917	41	"
"	12	20,530	"	15.03	"	26.7	44.84		11.25	3.32	58,868	0.0165	504.5	0.25009	50	"
MATERIAL C2																
26	3	2,710	30.48	4.39	0.0005	12.5	20.27		3.84	1.37	6,356	0.0125	77.8	0.00356	50	Smooth
"	4	3,500	"	5.18	"	13.5	22.16		4.42	1.47	8,220	0.0126	97.9	0.01033	60	"
"	5	4,616	"	6.31	"	13.5	23.99		5.27	1.61	10,613	0.0131	126.4	0.02435	52	Waves
"	6	5,918	"	7.53	"	13.5	25.79		6.16	1.74	13,341	0.0135	158.9	0.03150	42	"
"	7	7,051	"	8.47	"	13.5	27.31		6.77	1.82	15,524	0.0136	184.9	0.05829	46	"
"	8	8,269	"	9.48	"	13.5	28.62		7.44	1.91	17,875	0.0138	212.9	0.07896	46	"
"	9	9,486	"	10.79	"	13.5	28.83	No Observations	8.44	2.04	20,427	0.0149	243.3	0.12029	23	"
"	10	11,355	"	12.22	"	13.5	30.48		9.33	2.14	23,878	0.0151	284.4	0.08970	41	"
"	11	13,252	"	13.81	"	13.6	31.49		10.39	2.26	27,542	0.0157	327.2	0.12525	45	"
"	12	15,234	"	15.54	"	13.7	32.16		11.55	2.38	31,368	0.0165	371.4	0.10665	35	"
27	2	1,441	"	2.38	0.0010	10.9	19.90		2.19	1.47	3,420	0.0124	43.6	0.01571	30	Smooth
"	3	2,212	"	3.17	"	11.0	22.89		2.87	1.68	5,161	0.0130	65.7	0.03638	45	Waves
"	4	3,356	"	4.18	"	11.2	26.37		3.69	1.90	7,686	0.0133	97.3	0.06986	40	"
"	5	4,757	"	5.15	"	11.5	30.30		4.42	2.08	10,661	0.0130	133.9	0.12691	46	"
"	6	6,428	"	6.37	"	11.7	33.10		5.36	2.29	14,192	0.0136	177.4	0.16370	44	"
"	7	8,070	-	7.41	"	11.8	35.75		6.10	2.45	17,518	0.0137	218.1	0.22033	49	"
"	8	11,044	"	9.17	"	11.9	39.50		7.25	2.67	23,060	0.0139	286.4	0.29722	26	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 35 (CONTINUED)
U. S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS.
LIGHT-WEIGHT MATERIALS C3, C4 AND C5

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G(2) grams per second per centimeter	Duration of run minutes	Bed condition
Table	Run Number						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
MATERIAL C3																
28	8	8,665	30.48	9.97	0.0005	23.1	28.53	No Observations	7.83	1.96	24,047	0.0143	223.4	0.00091	72	Smooth
"	9	10,647	"	11.52	"	23.0	30.33		8.81	2.08	28,731	0.0146	267.2	0.00174	60	"
"	10	12,884	"	12.92	"	23.0	32.71		9.51	2.16	33,452	0.0142	311.1	0.00579	94	Waves
"	11	15,008	"	14.30	"	23.2	34.44		10.24	2.24	38,047	0.0142	352.7	0.02815	60	"
"	12	17,358	"	15.58	"	22.6	36.58		10.73	2.29	41,755	0.0138	392.5	0.04679	78	"
"	13	19,793	"	16.92	"	22.4	38.37		11.25	2.35	45,683	0.0136	431.7	0.06486	64	"
"	14	23,248	"	18.62	"	22.6	40.97		11.73	2.40	51,128	0.0131	480.6	0.07275	51	"
"	15	27,241	"	20.79	"	22.6	43.01		12.53	2.48	57,330	0.0130	538.9	0.15584	54	"
"	16	30,837	"	22.80	"	22.6	44.38		13.26	2.55	62,606	0.0131	588.5	0.17899	45	"
29	6	4,927	"	5.88	0.0010	23.0	27.49		5.18	2.25	15,312	0.0160	142.4	0.00087	45	Smooth
"	7	6,570	"	6.86	"	23.0	31.42		5.85	2.40	19,763	0.0152	183.8	0.01860	50	Waves
"	8	7,929	"	7.86	"	23.0	33.07		6.61	2.55	23,505	0.0156	218.6	0.06449	60	"
"	9	9,345	"	8.81	"	23.0	34.81		7.41	2.70	27,731	0.0160	257.9	0.07598	60	"
"	10	11,044	"	9.78	"	23.1	37.03		7.96	2.80	31,733	0.0158	294.8	0.11347	60	"
"	11	12,941	"	10.94	"	23.2	38.80		8.72	2.93	36,494	0.0160	338.3	0.15626	45	"
"	12	14,951	"	12.07	"	23.3	40.63		9.45	3.05	41,514	0.0161	384.0	0.19512	45	"
"	13	17,132	"	13.26	"	23.3	42.40		10.21	3.16	46,800	0.0163	432.9	0.23315	26	"
MATERIAL C4																
30	5	2,914	30.48	4.60	0.0005	23.3	20.76	No Observations	3.99	1.40	8,951	0.0126	82.8	0.00438	60	Smooth
"	6	3,964	"	5.58	"	24.0	23.32		4.69	1.52	12,022	0.0125	109.4	0.01761	55	Waves
"	7	5,267	"	6.68	"	24.3	25.88		5.43	1.63	15,576	0.0124	140.5	0.05494	47	"
"	8	6,796	"	8.02	"	24.0	27.83		6.37	1.77	19,484	0.0128	177.3	0.09156	60	"
"	9	8,184	"	9.20	"	24.1	29.17		7.16	1.88	23,160	0.0132	208.9	0.09714	60	"
"	10	9,883	"	10.52	"	24.1	30.85		7.99	1.98	27,328	0.0134	246.5	0.10500	40	"
"	11	11,893	"	11.86	"	24.1	32.92		8.72	2.07	31,829	0.0134	287.1	0.14510	56	"
"	12	14,470	"	13.50	"	24.2	35.14		9.54	2.17	37,080	0.0133	335.2	0.22571	40	"
"	13	16,679	"	14.78	"	24.2	37.00		10.09	2.22	41,294	0.0131	373.3	0.23728	32	"
31	3	1,603	"	2.59	0.0010	23.0	20.30		2.41	1.54	5,258	0.0130	48.9	0.00661	65	Smooth
"	4	2,212	"	3.23	"	23.0	22.46		2.93	1.70	7,075	0.0133	65.8	0.02869	75	Waves
"	5	2,968	"	3.90	"	23.0	24.96		3.51	1.86	9,419	0.0136	87.6	0.07999	82	"
"	6	3,993	"	4.69	"	23.0	27.92		4.11	2.01	12,344	0.0135	114.8	0.10872	73	"
"	7	5,352	"	5.64	"	23.0	31.15		4.82	2.17	16,140	0.0134	150.1	0.14386	74	"
"	8	6,626	"	6.58	"	22.9	33.01		5.52	2.33	19,528	0.0139	182.2	0.19098	66	"
"	9	8,269	"	7.62	"	22.9	35.60		6.28	2.48	23,966	0.0140	223.6	0.24927	48	"
"	10	9,939	"	8.66	"	23.0	37.67		6.98	2.62	28,269	0.0142	262.9	0.30053	37	"
"	11	11,638	"	9.60	"	23.0	39.78		7.59	2.73	32,462	0.0143	301.9	0.31582	35	"
MATERIAL C5																
32	7	10,930	30.48	11.73	0.0005	14.9	30.57	No Observations	8.93	2.09	23,822	0.0146	273.0	0.02646	46	Waves
"	8	13,252	"	13.11	"	14.9	33.16		9.60	2.17	27,775	0.0141	318.3	0.06490	59	"
"	9	15,574	"	14.54	"	15.0	35.14		10.27	2.25	31,602	0.0140	360.9	0.12773	67	"
"	10	18,123	"	16.03	"	15.0	37.09		10.94	2.32	35,534	0.0138	405.8	0.16494	64	"
"	11	21,039	"	17.74	"	15.1	38.92		11.67	2.39	39,842	0.0137	454.2	0.19718	54	"
"	12	23,701	"	19.17	"	15.3	40.57		12.19	2.45	43,607	0.0136	494.5	0.28730	57	"
33	5	6,541	"	6.89	0.0010	15.0	31.15		5.88	2.40	16,042	0.0154	183.2	0.08681	66	"
"	6	8,070	"	7.99	"	15.0	33.16		6.71	2.57	19,483	0.0157	222.5	0.16494	42	"
"	7	9,713	"	8.96	"	14.3	35.57		7.38	2.69	22,513	0.0156	262.5	0.23976	60	"
"	8	11,780	"	10.39	"	14.3	37.19		8.41	2.87	26,827	0.0163	312.8	0.32492	38	"
"	9	13,649	"	11.55	"	14.4	38.77		9.20	3.01	30,697	0.0166	356.7	0.34104	40	"
"	10	15,801	"	12.53	"	14.5	41.39		9.72	3.09	34,711	0.0162	402.3	0.37742	61	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 35 (CONTINUED)

U. S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS.

LIGHT-WEIGHT MATERIALS C6, C7, C8 AND R1.

Author's references							Velocity centimeters per second									
Table	Run Number	Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Mean V_m	Bottom V_b	Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G(2) grams per second per centimeter	Duration of run minutes	Bed condition
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
							MATERIAL C6									
34	3	2,888	30.48	4.39	0.0005	13.6	21.58	No Observations	3.78	1.36	6,869	0.0117	81.6	0.00934	61	Smooth
"	4	4,219	"	5.70	"	13.3	24.29		4.75	1.53	9,641	0.0121	115.4	0.01893	40	Waves
"	5	5,692	"	7.10	"	13.0	26.30		5.76	1.68	12,562	0.0127	151.5	0.03505	65	"
"	6	7,249	"	8.72	"	13.0	27.28		6.98	1.85	15,788	0.0139	190.4	0.04386	52	"
"	7	8,835	"	10.30	"	13.5	28.13		8.14	2.00	19,228	0.0149	229.0	0.07482	65	"
"	8	10,647	"	11.55	"	13.5	30.24		8.84	2.08	22,443	0.0147	267.3	0.09094	55	"
"	9	12,573	"	13.05	"	13.4	31.61		9.78	2.19	25,866	0.0150	309.1	0.09355	55	"
"	10	14,527	"	14.33	"	13.2	33.25		10.45	2.27	28,958	0.0149	347.5	0.11285	56	"
35	3	1,603	"	2.53	0.0010	14.0	20.79		2.32	1.51	4,102	0.0124	48.2	0.01889	27	Smooth
"	4	2,234	"	3.20	"	11.5	22.89		2.90	1.69	5,287	0.0130	66.4	0.03691	120	Waves
"	5	3,214	"	3.96	"	13.3	26.61		3.51	1.86	7,803	0.0127	93.4	0.08102	30	"
"	6	4,276	"	4.85	"	12.3	28.96		4.21	2.05	9,911	0.0132	121.9	0.09921	49	"
"	7	5,635	"	5.82	"	13.0	31.76		4.94	2.20	13,010	0.0134	156.9	0.15626	45	"
"	8	7,419	"	7.01	"	13.0	34.72		5.79	2.38	16,667	0.0137	201.0	0.17155	45	"
"	9	9,826	"	8.38	"	13.1	38.47		6.71	2.57	21,455	0.0136	258.1	0.28565	31	"
"	10	11,638	"	9.60	"	13.2	39.78		7.59	2.73	25,158	0.0143	301.9	0.35344	42	"
"	11	13,337	"	10.45	"	13.2	41.85		8.08	2.82	28,175	0.0141	338.1	0.37700	38	"
							MATERIAL C7									
36	4	13,139	30.48	11.16	0.0010	11.1	38.65		8.90	2.96	27,065	0.0163	344.0	0.11182	58	Waves
"	5	16,367	"	12.95	"	11.2	41.45		10.06	3.14	34,750	0.0165	417.0	0.33938	60	"
							MATERIAL C8									
37	4	3,738	30.48	5.52	0.0005	15.3	22.22	No Observations	4.69	1.52	9,181	0.0131	104.2	0.00504	45	Smooth
"	5	5,012	"	6.68	"	15.4	24.63		5.52	1.65	12,025	0.0132	136.0	0.02367	69	Waves
"	6	6,428	"	7.77	"	15.3	27.13		6.22	1.75	14,863	0.0130	168.7	0.05043	61	"
"	7	7,929	"	9.02	"	15.4	28.83		7.04	1.86	17,949	0.0132	203.0	0.09880	45	"
"	8	9,656	"	10.27	"	15.4	30.85		7.77	1.95	21,194	0.0132	239.7	0.14014	48	"
"	9	11,836	"	11.73	"	15.5	33.10		8.60	2.05	25,217	0.0132	284.7	0.20214	32	"
38	3	2,124	"	3.11	0.0010	16.2	22.40		2.83	1.67	5,712	0.0131	63.4	0.03803	60	"
"	4	3,186	"	4.02	"	15.6	25.97		3.57	1.87	8,225	0.0132	92.7	0.09673	61	"
"	5	4,191	"	4.79	"	16.1	28.74		4.18	2.02	10,800	0.0133	120.1	0.12567	60	"
"	6	5,720	"	5.88	"	17.0	31.91		5.00	2.21	14,696	0.0135	159.6	0.19346	47	"
"	7	7,391	"	6.98	"	17.9	34.75		5.79	2.38	18,999	0.0136	201.2	0.27283	37	"
"	8	9,090	"	8.08	"	17.8	36.91		6.55	2.54	22,768	0.0139	241.8	0.38196	20	"
							MATERIAL R1									
39	7	5,493	30.48	10.21	0.0001	18.6	17.65	No Observations	6.64	0.81	11,269	0.0093	117.2	0.00785	34	Waves
"	8	6,881	"	12.13	"	18.9	18.62		7.56	0.86	13,643	0.0096	140.8	0.03100	54	"
"	9	8,523	"	13.84	"	19.1	20.21		7.92	0.88	15,589	0.0091	160.1	0.06862	50	"
"	10	10,477	"	16.09	"	19.1	21.37		8.63	0.92	17,955	0.0092	184.4	0.12195	86	"
"	11	12,884	"	18.59	"	19.0	22.74		9.11	0.95	20,097	0.0089	207.2	0.15956	68	"
40	5	2,189	"	4.69	0.0003	19.7	15.30		4.11	1.10	6,228	0.0135	62.9	0.01240	60	Smooth
"	6	3,021	"	5.94	"	19.8	16.67		5.12	1.23	8,472	0.0143	85.4	0.03018	45	Waves
"	7	3,993	"	7.19	"	19.9	18.20		6.04	1.33	10,935	0.0147	109.9	0.06242	53	"
"	8	5,069	"	8.50	"	19.5	19.57		6.98	1.43	13,458	0.0150	136.6	0.11616	49	"
"	9	6,343	"	10.06	"	19.6	20.70		8.11	1.55	16,575	0.0157	167.9	0.14096	55	"
"	10	7,476	"	11.55	"	19.8	21.24		9.20	1.65	19,385	0.0166	195.4	0.15791	47	"
"	11	9,146	"	13.69	"	19.9	21.92		10.79	1.78	23,532	0.0179	236.5	0.15708	48	"
"	12	11,185	"	15.76	"	19.9	23.29		12.10	1.89	28,040	0.0182	281.8	0.23563	46	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 35 (CONTINUED)
U. S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS
LIGHT-WEIGHT MATERIALS R2, G1, G2 AND G3

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
Table	Run Number						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
MATERIAL R2																
41	4	2,347	30.48	5.67	0.0001	16.0	13.59	No Observations	4.33	0.65	5,274	0.0091	58.8	0.00856	60	Waves
"	5	3,214	"	7.04	"	15.7	14.97		5.12	0.71	6,815	0.0092	76.6	0.01674	57	"
"	6	4,049	"	8.29	"	15.5	16.03		5.79	0.75	8,220	0.0094	92.8	0.03018	70	"
"	7	5,040	"	9.75	"	15.7	16.95		6.55	0.80	9,875	0.0096	111.0	0.04795	57	"
"	8	6,258	"	11.37	"	16.0	18.04		7.28	0.85	11,776	0.0097	131.3	0.07027	47	"
"	9	7,504	"	12.89	"	16.1	19.08		7.83	0.88	13,435	0.0096	149.4	0.08970	65	"
"	10	9,175	"	14.81	"	16.0	20.33		8.41	0.91	15,336	0.0094	171.0	0.12236	55	"
"	11	11,129	"	16.89	"	15.3	21.61		8.87	0.93	16,890	0.0092	191.7	0.15460	56	"
42	3	1,325	"	3.32	0.0003	15.7	13.08		2.99	0.94	3,479	0.0128	39.1	0.01257	42	Smooth
"	4	2,081	"	4.51	"	15.7	15.15		3.96	1.08	5,338	0.0133	60.0	0.04382	60	Waves
"	5	2,914	"	5.82	"	15.7	16.43		5.03	1.22	7,349	0.0144	82.6	0.06325	45	"
"	6	3,908	"	7.19	"	15.5	17.83		6.10	1.34	9,637	0.0150	108.8	0.07606	60	"
"	7	5,154	"	8.75	"	15.5	19.32		7.22	1.46	12,356	0.0155	139.5	0.11616	53	"
"	8	6,258	"	10.06	"	15.6	21.34		8.14	1.55	15,413	0.0159	173.7	0.15460	48	"
"	9	7,476	"	11.58	"	15.7	21.18		9.27	1.65	17,464	0.0167	196.3	0.16535	58	"
"	10	8,920	"	13.23	"	16.0	23.23		10.39	1.75	21,650	0.0173	241.4	0.18643	52	"
"	11	10,647	"	15.18	"	16.2	23.01		11.73	1.86	24,315	0.0180	269.9	0.24017	47	"
MATERIAL G1																
43	4	2,585	30.48	6.16	0.0001	13.0	13.78	No Observations	4.69	0.68	5,357	0.0094	64.6	0.02398	43	Waves
"	5	3,653	"	7.68	"	13.5	15.61		5.46	0.73	7,154	0.0092	85.2	0.10252	51	"
"	6	4,870	"	9.42	"	13.5	16.98		6.31	0.79	8,992	0.0093	107.1	0.11285	57	"
"	7	6,088	"	11.16	"	13.6	17.89		7.16	0.84	10,783	0.0096	128.1	0.17693	59	"
"	8	7,419	"	12.74	"	13.7	19.11		7.71	0.87	12,430	0.0095	147.3	0.16866	44	"
"	9	8,920	"	14.54	"	13.6	20.12		8.35	0.90	14,141	0.0095	168.0	0.22695	26	"
44	3	1,150	"	3.14	0.0003	14.6	12.01		2.87	0.92	2,984	0.0135	34.5	0.03100	81	Smooth
"	4	1,696	"	4.05	"	13.2	13.72		3.63	1.03	4,150	0.0138	49.8	0.09880	64	"
"	5	2,512	"	5.30	"	13.3	15.54		4.63	1.17	6,015	0.0144	72.0	0.15832	60	Waves
"	6	3,384	"	6.58	"	13.0	16.86		5.64	1.29	7,886	0.0151	95.1	0.19594	58	"
"	7	4,502	"	7.99	"	13.1	18.50		6.68	1.40	10,274	0.0154	123.6	0.27283	43	"
"	8	5,720	"	9.60	"	13.0	19.54		7.89	1.52	12,786	0.0163	154.2	0.29970	43	"
"	9	7,164	"	11.37	"	13.0	20.67		9.17	1.64	15,713	0.0170	189.5	0.31417	50	"
"	10	9,033	"	13.59	"	13.0	21.79		10.73	1.78	19,386	0.0179	233.8	0.41462	20	"
MATERIAL G2																
45	3	1,495	30.48	4.18	0.0001	12.0	11.73	No Observations	3.38	0.58	3,199	0.0089	39.6	0.00599	30	Waves
"	4	2,189	"	5.36	"	12.2	13.38		4.15	0.64	4,509	0.0090	55.5	0.01893	38	"
"	5	2,968	"	6.61	"	12.1	14.72		4.85	0.69	5,786	0.0090	71.4	0.03096	35	"
"	6	3,908	"	7.96	"	12.0	16.12		5.55	0.74	7,229	0.0090	89.5	0.07400	40	"
"	7	5,012	"	9.63	"	11.0	17.07		6.43	0.79	8,632	0.0094	109.8	0.09012	30	"
"	8	6,201	"	11.22	"	10.7	18.14		7.13	0.84	10,054	0.0095	129.3	0.12401	30	"
"	9	7,504	"	12.74	"	10.7	19.32		7.65	0.87	11,493	0.0093	147.8	0.14675	30	"
"	10	9,033	"	14.57	"	10.5	20.33		8.29	0.90	13,052	0.0094	168.5	0.16204	30	"
46	1	714	"	2.23	0.0003	9.7	10.52		2.07	0.78	1,650	0.0124	21.8	0.01505	45	"
"	2	1,195	"	3.26	"	10.2	12.01		2.99	0.94	2,762	0.0139	35.9	0.04010	45	"
"	3	1,753	"	4.21	"	10.8	13.69		3.78	1.05	4,039	0.0143	51.7	0.06866	30	"
"	4	2,489	"	5.30	"	11.0	15.39		4.63	1.17	5,605	0.0145	71.3	0.08867	30	"
"	5	3,412	"	6.61	"	11.0	16.92		5.67	1.29	7,539	0.0151	95.9	0.10955	40	"
"	6	4,616	"	8.11	"	11.0	18.68		6.77	1.41	9,945	0.0154	126.5	0.16556	35	"
"	7	5,692	"	9.45	"	11.1	19.75		7.74	1.51	12,030	0.0160	152.9	0.19408	30	"
MATERIAL G3																
47	5	2,441	30.48	5.79	0.0001	11.8	13.84	No Observations	4.39	0.65	4,884	0.0090	60.8	0.03266	46	Waves
"	6	3,214	"	6.98	"	12.0	15.12		5.06	0.70	6,179	0.0090	76.5	0.08888	52	"
"	7	4,078	"	8.38	"	11.3	15.97		5.88	0.76	7,429	0.0095	93.9	0.12939	65	"
"	8	5,182	"	10.03	"	11.9	16.95		6.74	0.81	9,180	0.0098	114.2	0.17486	56	"
"	9	6,485	"	11.80	"	11.0	18.04		7.53	0.86	10,676	0.0099	135.8	0.20669	58	"
"	10	7,929	"	13.50	"	10.5	19.26		8.14	0.89	12,146	0.0098	156.8	0.23067	30	"
48	4	2,016	"	4.45	0.0003	15.5	14.87		3.93	1.08	5,173	0.0135	58.4	0.10210	45	"
"	5	2,537	"	5.15	"	13.7	16.15		4.45	1.14	6,073	0.0135	71.9	0.15874	45	"
"	6	3,157	"	6.16	"	10.0	16.82		5.27	1.25	6,763	0.0145	88.6	0.20173	32	"
"	7	3,766	"	7.16	"	10.0	17.25		6.10	1.34	8,031	0.0156	105.2	0.23976	39	"
"	8	4,474	"	7.96	"	10.0	18.44		6.68	1.40	9,405	0.0154	123.2	0.25506	42	"
"	9	5,380	"	9.14	"	10.0	19.29		7.56	1.49	11,130	0.0161	145.8	0.31624	35	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 35 (CONTINUED)
U. S. WATERWAYS EXPERIMENT STATION BED-LOAD EXPERIMENTS.
LIGHT-WEIGHT MATERIALS G4, G5 AND G6

Author's references: Table	Author's references: Run Number	Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second: Mean V_m	Velocity centimeters per second: Bottom V_b	Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
MATERIAL G4																
49	2	1,195	30.48	3.54	0.0001	13.7	11.09	No Observations	2.93	0.54	2,745	0.0086	32.5	0.00926	31	Waves
"	3	1,892	"	4.94	"	13.4	12.56		3.90	0.62	4,100	0.0092	49.0	0.02728	30	"
"	4	2,560	"	6.34	"	14.0	13.26		4.91	0.69	5,540	0.0101	65.1	0.04361	30	"
"	5	3,440	"	7.62	"	14.3	14.81		5.58	0.74	7,084	0.0098	82.6	0.06821	30	"
"	6	4,616	"	9.48	"	14.5	15.97		6.64	0.81	9,146	0.0103	106.0	0.09838	30	"
"	7	5,607	"	11.06	"	14.5	16.61		7.53	0.86	10,794	0.0107	125.1	0.11988	30	"
50	1	660	"	2.13	0.0003	14.0	10.15		1.98	0.76	1,711	0.0125	20.1	0.00542	45	Smooth
"	2	1,195	"	3.20	"	14.0	12.25		2.93	0.93	3,055	0.0134	35.9	0.04795	45	Waves
"	3	1,892	"	4.42	"	14.0	14.05		3.93	1.08	4,698	0.0142	55.2	0.08392	32	"
"	4	2,585	"	5.46	"	14.0	15.54		4.75	1.18	6,281	0.0146	73.8	0.11575	30	"
"	5	3,440	"	6.71	"	14.0	16.82		5.76	1.30	8,247	0.0153	96.9	0.15915	30	"
"	6	4,502	"	8.23	"	14.0	17.95		6.95	1.43	10,621	0.0163	124.8	0.17982	30	"
MATERIAL G5																
51	3	1,424	30.48	4.51	0.0001	14.2	10.36	No Observations	3.81	0.61	3,376	0.0109	39.5	0.02356	30	Smooth
"	4	2,418	"	6.22	"	13.9	12.77		4.88	0.69	5,282	0.0105	62.3	0.13559	58	Waves
"	5	3,104	"	7.28	"	14.6	13.99		5.49	0.73	6,644	0.0103	76.8	0.24637	31	"
"	6	3,738	"	8.32	"	14.2	14.75		6.10	0.77	7,692	0.0105	90.0	0.39023	34	"
"	7	4,644	"	9.66	"	14.2	15.76		6.83	0.82	9,197	0.0106	107.6	0.44025	32	"
52	3	1,034	"	3.02	0.0003	14.9	11.25		2.77	0.90	2,723	0.0141	31.2	0.12360	30	Smooth
"	4	1,478	"	3.78	"	15.3	12.83		3.41	1.00	3,859	0.0142	43.8	0.27159	55	Waves
"	5	1,996	"	4.63	"	14.2	14.14		4.11	1.10	4,966	0.0146	58.1	0.29474	47	"
"	6	2,684	"	5.73	"	14.3	15.36		5.03	1.22	6,630	0.0154	77.3	0.39064	31	"
MATERIAL G6																
53	2	1,034	30.48	3.44	0.0001	11.2	9.85	No Observations	2.96	0.54	2,301	0.0097	29.2	0.04597	47	Waves
"	3	1,640	"	4.60	"	12.4	11.67		3.75	0.61	3,576	0.0096	43.8	0.07069	60	"
"	4	2,302	"	5.82	"	13.0	12.98		4.54	0.67	4,884	0.0098	58.9	0.10169	55	"
"	5	3,129	"	7.16	"	12.0	14.33		5.33	0.72	6,171	0.0099	76.4	0.16329	32	"
"	6	3,964	"	8.50	"	12.9	15.30		6.10	0.77	7,711	0.0101	93.3	0.24389	34	"
54	2	714	"	2.44	0.0003	9.7	9.60		2.29	0.82	1,664	0.0145	22.0	0.04299	60	"
"	3	1,150	"	3.17	"	11.3	11.89		2.90	0.92	2,727	0.0137	34.5	0.12897	40	"
"	4	1,696	"	4.08	"	12.2	13.62		3.66	1.04	4,045	0.0140	49.8	0.19015	39	"
"	5	2,302	"	5.03	"	12.6	15.03		4.42	1.14	5,443	0.0144	66.4	0.32657	30	"
"	6	3,075	"	6.22	"	13.0	16.22		5.39	1.26	7,247	0.0152	87.4	0.37990	22	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 36
BED-LOAD EXPERIMENTS OF T. Y. LIU
IOWA INSTITUTE OF HYDRAULIC RESEARCH

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, $G^{(2)}$ grams per second per centimeter	Duration of run minutes	Bed condition
Page	Run Number						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
MATERIAL I																
17a	3	64,591	81.92	12.13	0.00175	29.5	64.92	48.16	10.06	4.15	80,414	0.0139	653.1	0.00095	52	Smooth
″	4	73,341	″	12.89	0.00225	29.5	69.49	51.82	10.85	4.89	92,862	0.0155	754.0	0.00120	41	″
″	5	77,871	″	13.29	0.00215	29.5	71.32	51.51	11.06	4.83	97,178	0.0150	788.8	0.00124	50	″
17b	4	48,252	81.92	9.45	0.00190	27.2	62.18	38.10	8.02	3.87	58,708	0.0130	498.7	0.00074	50	″
″	5	54,085	″	10.06	0.00225	″	65.53	40.84	8.60	4.36	66,340	0.0141	563.6	0.00054	45	″
″	6	57,398	″	10.61	0.00215	″	65.84	40.23	8.99	4.35	69,733	0.0142	591.9	0.00050	51	″
″	7	58,134	″	10.79	0.00200	″	65.84	42.67	9.05	4.21	70,206	0.0137	595.9	0.00091	41	″
″	8	62,014	″	10.97	0.00210	″	68.88	42.67	9.17	4.35	74,429	0.0135	631.6	0.00091	40	″
″	9	64,562	″	11.06	0.00185	″	71.63	45.72	8.93	4.02	75,351	0.0120	639.7	0.00182	48	″
″	10	69,093	″	11.58	0.00225	27.0	72.85	45.11	9.63	4.61	82,358	0.0137	701.5	0.00380	65	″
″	11	74,756	″	12.13	0.00210	27.0	75.29	46.02	9.85	4.50	86,999	0.0130	741.6	0.00570	52	″
17c	3	34,943	81.92	6.10	0.00310	29.0	70.10	47.85	No calculations made as data appears to be in error					0.00112	45	″
″	4	44,174	″	6.77	0.00350	29.0	79.86	53.94						0.00269	37	″
″	5	49,583	″	7.62	0.00210	29.5	79.55	52.73						0.00711	52	Local Riffles
″	6	50,687	″	7.99	0.00200	30.0	77.42	48.77						0.00550	63	Smooth
″	7	53,179	″	8.38	0.00150	30.0	77.42	49.07						0.00517	50	″
″	8	54,000	″	8.23	0.00150	29.5	80.16	47.24						0.02708	42	Local Riffles
″	9	54,652	″	8.08	0.00080	29.0	82.60	50.60						0.02418	45	″
″	11	56,577	″	8.87	0.00200	30.0	77.72	43.89						0.02079	60	General Riffles
″	12	57,200	″	8.90	0.00120	29.5	78.64	47.85						0.00608	47	Smooth
″	14	61,164	″	9.54	0.00205	30.0	78.33	44.50						0.01608	40	″
″	15	63,033	″	8.84	0.00100	29.5	87.17	51.82						0.04291	30	Local Riffles
″	16	66,035	″	9.94	0.00160	30.0	81.08	44.50						0.01778	53	″
″	17	66,176	″	10.06	0.00210	30.0	80.16	43.89						0.00723	41	Smooth
″	18	69,829	″	10.61	0.00110	30.0	79.55	43.28						0.04093	30	″
″	20	70,226	″	12.01	0.00060	29.5	71.32	43.28						0.00248	35	″
″	21	70,877	″	10.12	0.00170	29.5	85.34	49.07						0.09549	45	General Riffles
″	22	73,964	″	10.64	0.00200	30.6	84.73	55.47						0.06647	35	″
17d	26	23,276	81.92	5.03	0.00400	27.0	56.69	42.06	4.63	4.26	30,827	0.0144	262.5	0.00128	38	Local Riffles
″	27	25,542	″	5.27	0.00400	″	59.13	42.67	4.85	4.36	33,632	0.0142	286.8	0.00124	60	″
″	28	28,034	″	5.67	0.00400	″	60.35	44.20	5.21	4.52	36,918	0.0146	314.4	0.00232	32	″
″	29	31,460	″	6.00	0.00380	″	64.01	45.42	5.43	4.50	40,758	0.0138	347.6	0.00161	31	″
″	30	34,575	″	6.40	0.00350	″	65.84	44.20	5.73	4.43	44,280	0.0134	377.3	0.00587	40	″
″	31	38,228	″	6.74	0.00480	″	69.19	47.85	6.13	5.37	49,749	0.0196	424.1	0.00881	45	General Riffles
″	32	40,323	″	7.16	0.00430	″	68.88	49.38	6.46	5.22	52,242	0.0153	455.0	0.01885	63	″
″	33	41,343	″	7.16	0.00460	″	70.71	52.73	6.49	5.41	53,879	0.0155	458.9	0.02480	35	″
″	34	43,665	″	7.68	0.00420	″	69.49	51.51	6.92	5.34	56,432	0.0157	480.9	0.02613	45	″
″	35	48,478	″	7.83	0.00450	″	75.59	57.61	7.01	5.56	62,193	0.0151	529.9	0.07755	30	″
″	36	53,972	″	8.14	0.00420	″	81.08	62.79	7.13	5.42	67,871	0.0138	578.1	0.09260	31	″
″	37	53,972	″	8.23	0.00450	26.5	79.86	63.70	7.29	5.67	67,492	0.0147	582.2	0.09921	25	″
″	38	59,097	″	8.69	0.00450	26.5	83.21	63.09	7.62	5.80	73,557	0.0145	634.1	0.18437	20	″
17e	4	19,029	81.92	3.17	0.01000	29.0	73.15	No Observations	2.99	5.41	26,646	0.0132	218.7	0.00537	55	Smooth
″	6	20,643	″	3.26	0.00800	30.0	77.11		3.02	4.87	28,981	0.0113	232.9	0.01563	38	″
″	7	23,022	″	3.57	0.00640	29.0	78.64		3.26	4.52	31,274	0.0104	256.4	0.03530	85	Local Riffles
″	8	23,361	″	3.60	0.00750	30.3	79.25		3.32	4.94	32,909	0.0113	263.1	0.07507	30	″
″	9	24,664	″	3.87	0.00730	30.3	77.72		3.57	5.06	34,644	0.0119	277.5	0.07606	37	General Riffles Scouring
″	10	25,259	″	3.69	0.00630	29.0	83.82		3.35	4.55	34,274	0.0098	280.8	0.07189	31	Local Riffles
″	11	25,344	″	3.96	0.00400	30.0	78.33		3.48	3.69	33,897	0.0086	272.6	0.07916	45	General Riffles Scouring
″	13	28,034	″	4.18	0.00740	30.5	81.99		3.84	5.28	39,503	0.0119	314.8	0.10653	33	″
″	14	29,365	″	4.18	0.00730	30.5	85.95		3.81	5.22	41,088	0.0113	327.5	0.08681	32.5	″
″	15	33,782	″	6.43	0.00175	30.5	64.01		5.36	3.03	43,080	0.0093	343.1	0.03315	32	″
17f	21	14,668	81.92	3.02	0.00975	26.5	59.44	47.55	2.90	5.27	19,993	0.0157	172.4	0.00103	30	Smooth
″	22	16,537	″	3.35	0.01000	″	60.05	50.29	3.20	5.60	22,318	0.0168	192.2	0.00595	25	″
″	23	17,925	″	3.41	0.00950	″	64.01	52.43	3.26	5.51	24,244	0.0155	208.7	0.01095	27	″
″	24	18,548	″	3.47	0.00980	″	65.23	53.64	3.32	5.65	25,168	0.0157	216.6	0.02881	21	″
″	25	18,802	″	3.54	0.00950	″	65.23	50.60	3.35	5.59	25,403	0.0156	218.5	0.02216	29	″
″	26	18,887	″	3.54	0.00980	″	64.92	55.17	3.38	5.70	25,508	0.0160	219.4	0.03059	23	″
″	27	20,530	″	3.66	0.01000	″	68.58	60.66	3.48	5.84	27,679	0.0155	238.7	0.06862	31	General Riffles
″	28	23,730	″	3.99	0.00965	″	72.54	61.57	3.78	5.98	31,847	0.0153	274.2	0.12360	32	″
″	29	27,212	″	4.54	0.00900	″	73.15	66.75	4.27	6.14	36,252	0.0159	312.4	0.22157	23	General Riffles Scouring
″	30	33,414	″	4.97	0.00880	″	82.60	70.10	4.60	6.30	44,149	0.0146	380.0	0.25092	30	—

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 36 (CONTINUED)
BED-LOAD EXPERIMENTS OF T. Y. LIU
IOWA INSTITUTE OF HYDRAULIC RESEARCH

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, $G^{(2)}$ grams per second per centimeter	Duration of run minutes	Bed condition
Page	Run Number						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
MATERIAL II																
17g	3	34,716	81.92	7.99	0.00125	29.0	53.04	36.58	6.68	2.86	43,176	0.0110	354.3	0.00037	32	Smooth
"	4	38,143	"	8.41	0.00145	"	55.47	36.88	7.10	3.18	48,042	0.0118	393.8	0.00050	26	"
"	5	40,606	"	8.75	0.00145	"	56.69	39.32	7.35	3.23	50,786	0.0118	416.7	0.00107	23	"
"	6	43,750	"	9.14	0.00150	"	58.52	40.54	7.62	3.35	54,381	0.0119	445.9	0.00103	24	"
"	7	48,478	"	9.51	0.00125	"	62.18	40.84	7.53	3.04	57,092	0.0102	468.2	0.00165	30	"
"	8	50,404	"	10.09	0.00140	"	60.96	42.67	8.20	3.36	60,953	0.0116	499.9	0.00405	33.5	"
"	9	53,660	"	10.76	0.00175	"	60.96	47.55	9.08	3.95	67,524	0.0139	553.5	0.00802	40	"
"	10	57,512	"	10.97	0.00170	"	64.01	50.60	9.08	3.89	70,903	0.0130	581.2	0.00397	25	"
"	11	59,182	"	11.06	0.00170	"	65.23	48.16	9.08	3.89	72,254	0.0128	592.3	0.00599	33	"
"	12	64,279	"	11.55	0.00200	"	66.45	48.16	9.69	4.36	78,549	0.0142	643.9	0.00984	25	"
"	13	65,752	"	11.83	0.00225	29.5	67.97	50.60	10.03	4.70	83,941	0.0151	681.7	0.01831	27	"
"	14	70,084	"	12.13	0.00225	29.5	70.41	49.68	10.18	4.74	88,273	0.0147	716.8	0.02179	25	"
"	15	71,925	"	12.22	0.00225	29.5	71.93	50.60	10.18	4.74	90,178	0.0144	732.2	0.02096	26	"
17h	4	28,798	81.92	6.61	0.00250	29.0	53.04	36.58	5.97	3.83	38,642	0.0144	316.6	0.00103	36	"
"	5	30,582	"	6.92	0.00200	28.5	53.95	37.19	6.10	3.46	39,768	0.0128	329.1	0.00074	33	"
"	6	34,547	"	7.32	0.00220	"	57.61	40.84	6.43	3.72	44,799	0.0131	370.4	0.00169	29	"
"	7	37,180	"	7.62	0.00220	"	59.74	45.72	6.65	3.79	48,001	0.0129	397.3	0.00298	29	"
"	8	39,559	"	7.92	0.00195	"	60.96	46.02	6.77	3.60	49,881	0.0121	412.7	0.00434	34	"
"	9	43,127	"	8.32	0.00230	"	63.40	46.94	7.19	4.03	55,143	0.0131	455.8	0.01319	30	"
"	10	44,967	"	8.50	0.00180	"	64.62	46.02	7.07	3.53	55,251	0.0113	456.9	0.02129	25	Very Light Local Riffles
"	11	46,440	"	8.69	0.00220	"	65.23	47.85	7.41	4.00	58,423	0.0127	483.4	0.02712	26	Very Light Local Riffles
"	12	48,450	"	8.93	0.00220	"	66.14	47.24	7.59	4.05	60,702	0.0127	502.0	0.03038	31	"
"	13	48,705	"	9.08	0.00250	"	65.53	48.16	7.86	4.39	62,313	0.0140	515.1	0.03663	27	Light Local Riffles
"	14	51,508	"	9.14	0.00240	"	68.88	48.46	7.77	4.28	64,732	0.0130	535.2	0.04142	32	"
"	15	56,520	"	9.60	0.00240	"	71.93	49.07	8.08	4.36	70,252	0.0127	581.0	0.05771	24	"
"	16	58,899	"	9.94	0.00210	"	72.54	50.90	8.17	4.10	71,654	0.0119	592.7	0.06052	30	"
"	17	62,297	"	10.21	0.00200	"	74.37	51.21	8.29	4.03	74,559	0.0114	616.5	0.07214	24	"
"	18	65,865	"	10.64	0.00250	29.0	75.59	54.25	8.87	4.66	81,766	0.0132	670.5	0.13063	28	"
"	19	72,944	"	10.91	0.00245	29.0	81.69	54.56	8.84	4.61	88,056	0.0120	722.1	0.16618	25	"
17i	5	20,360	81.92	4.33	0.00500	28.5	57.30	45.42	4.05	4.46	28,089	0.0146	232.1	0.00281	35	Smooth
"	6	21,917	"	5.12	0.00400	"	52.12	43.59	4.79	4.33	30,156	0.0160	249.7	0.00074	34	"
"	7	22,314	"	4.94	0.00450	"	55.17	42.98	4.60	4.51	30,700	0.0156	253.8	0.00074	34	"
"	8	23,475	"	4.66	0.00500	"	61.57	47.24	4.33	4.61	32,222	0.0142	266.6	0.01191	25	"
"	9	24,777	"	4.91	0.00500	"	61.26	48.16	4.54	4.72	33,645	0.0147	278.1	0.02104	24	Light Local Riffles
"	10	24,975	"	5.36	0.00420	"	56.69	44.81	4.97	4.52	34,055	0.0155	281.7	0.00136	36	Smooth
"	11	25,513	"	5.00	0.00500	"	62.18	49.07	4.63	4.76	34,834	0.0147	287.9	0.02662	27	Light Local Riffles
"	12	27,552	"	5.39	0.00480	"	62.18	50.90	5.00	4.85	37,586	0.0151	310.9	0.04312	27	Local Riffles
"	13	29,110	"	5.55	0.00480	"	64.01	50.60	5.12	4.91	39,637	0.0149	327.7	0.05304	24	"
"	14	30,724	"	5.67	0.00485	"	66.14	54.25	5.21	4.98	41,683	0.0147	344.6	0.06023	23	General Riffles
"	15	33,131	"	5.91	0.00495	"	68.28	55.47	5.40	5.12	44,543	0.0147	368.7	0.09260	31.5	"
"	16	35,396	"	6.10	0.00495	28.7	71.02	63.09	5.55	5.19	47,809	0.0144	394.2	0.11926	28	"
"	17	37,803	"	6.28	0.00485	28.7	73.46	62.18	5.67	5.19	50,539	0.0140	416.5	0.14365	29	"
"	18	41,626	"	6.61	0.00480	28.7	76.81	66.45	5.91	5.27	55,119	0.0137	453.9	0.15729	30	"
"	19	45,109	"	7.01	0.00460	29.0	78.64	65.23	6.22	5.30	59,632	0.0136	489.1	0.19760	25	"
17j	4	9,656	81.92	2.44	0.00940	27.0	48.46	35.97	2.35	4.65	13,349	0.0164	113.9	0.00186	20	Smooth
"	5	10,364	"	2.62	0.00940	27.5	48.46	40.84	2.53	4.83	14,544	0.0172	122.6	0.00198	25	"
"	6	11,185	"	2.62	0.00910	27.0	52.12	40.84	2.53	4.75	15,477	0.0158	131.9	0.01290	23	Local Riffles
"	7	11,185	"	2.68	0.00910	27.0	50.90	42.06	2.59	4.81	15,479	0.0164	131.8	0.01939	28	"
"	8	11,553	"	2.68	0.00900	27.5	52.43	40.84	2.59	4.78	16,115	0.0158	135.8	0.00860	23	"
"	9	12,403	"	2.80	0.00940	27.0	53.95	44.20	2.71	5.00	17,179	0.0162	146.2	0.04237	28	"
"	10	13,366	"	3.02	0.00950	27.5	54.25	49.68	2.90	5.20	18,637	0.0169	157.3	0.03952	20	"
"	11	14,470	"	3.14	0.00955	27.0	56.08	47.85	3.02	5.32	19,865	0.0169	169.4	0.06697	31	"
"	12	14,640	"	3.05	0.00900	27.0	58.52	50.60	2.93	5.09	20,097	0.0154	171.5	0.10376	30	"
"	13	14,753	"	3.05	0.00900	27.5	59.13	50.29	2.93	5.09	20,524	0.0153	173.3	0.05936	25	Local Riffles
"	14	15,659	"	3.20	0.00900	27.5	59.74	50.60	3.05	5.19	21,600	0.0155	182.2	0.10087	25	"
"	15	16,311	"	3.32	0.00855	27.0	60.05	50.60	3.17	5.16	22,343	0.0154	190.4	0.10872	20	"
"	16	16,849	"	3.17	0.00880	27.5	64.62	53.04	3.02	5.10	23,134	0.0141	195.2	0.14469	21	General Riffles Souring
"	17	17,103	"	3.41	0.00920	27.5	61.26	55.78	3.26	5.42	23,697	0.0160	199.7	0.15047	22	"
"	18	18,717	"	3.47	0.00920	27.0	65.84	54.86	3.29	5.45	25,440	0.0150	216.6	0.16659	31	"
"	19	19,284	"	3.66	0.00900	27.5	64.31	59.13	3.48	5.54	26,510	0.0157	223.8	0.16039	24	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 36 (CONTINUED)
BED-LOAD EXPERIMENTS OF T. Y. LIU
IOWA INSTITUTE OF HYDRAULIC RESEARCH

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
Page	Run Number						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
MATERIAL III																
17K	2	25,542	81.92	6.71	0.00165	29.5	46.33	37.49	5.97	3.11	34,086	0.0134	276.6	0.00041	31	Smooth
"	3	28,345	"	7.19	0.00185	29.5	48.16	37.80	6.43	3.42	38,142	0.0143	309.7	0.00041	60	"
"	4	31,262	"	7.62	0.00165	29.5	50.29	39.01	6.68	3.29	41,341	0.0133	335.9	0.00116	32	"
"	5	33,357	"	8.23	0.00155	29.5	49.38	41.45	7.19	3.31	43,743	0.0138	355.0	0.00446	25	"
"	6	37,718	"	8.53	0.00200	30.0	53.95	42.67	7.53	3.84	50,584	0.0148	406.2	0.00484	30.5	"
"	7	42,107	"	8.93	0.00205	"	57.61	43.59	7.77	3.95	55,759	0.0143	447.6	0.01587	35	"
"	8	43,325	"	9.24	0.00225	"	57.30	43.28	8.14	4.24	58,071	0.0155	466.4	0.01625	32	"
"	9	46,779	"	9.85	0.00195	"	58.22	44.20	8.50	4.03	61,657	0.0147	494.9	0.02150	30.5	"
"	10	49,101	"	9.75	0.00175	"	61.26	43.28	8.23	3.76	62,786	0.0129	504.2	0.04300	39	"
"	11	50,687	"	10.61	0.00175	"	58.22	45.42	9.05	3.94	65,637	0.0145	526.9	0.03026	37.5	"
"	12	54,368	"	10.45	0.00195	"	63.40	49.07	8.84	4.11	69,787	0.0138	560.5	0.05403	25	"
"	13	58,304	"	10.79	0.00185	"	65.84	47.24	8.96	4.03	73,473	0.0131	589.9	0.07321	25	"
"	14	62,524	"	11.03	0.00225	"	69.19	48.46	9.30	4.53	80,098	0.0141	643.2	0.10603	28	Scouring
"	15	63,345	"	11.28	0.00180	"	68.58	49.99	9.21	4.03	78,615	0.0126	631.6	0.12732	20	Smooth
"	16	65,412	"	11.55	0.00225	30.5	68.88	53.04	9.75	4.64	84,298	0.0146	671.6	0.16907	23.5	Scouring
17l	2	20,303	81.92	5.39	0.00260	30.5	46.02	34.14	4.97	3.56	28,686	0.0150	228.7	0.00050	25	Smooth
"	3	24,664	"	5.85	0.00250	30.5	51.51	34.75	5.30	3.60	34,280	0.0137	273.0	0.00054	23	"
"	4	26,136	"	6.16	0.00250	30.5	51.82	36.58	5.58	3.70	36,268	0.0141	289.2	0.00170	22	"
"	5	27,043	"	6.34	0.00250	29.5	52.73	41.15	5.73	3.75	37,210	0.0141	302.1	0.00918	35	"
"	6	28,600	"	6.52	0.00250	30.5	53.34	43.89	5.88	3.80	39,078	0.0142	313.6	0.00719	31	"
"	7	30,384	"	6.77	0.00250	30.5	54.86	44.50	6.07	3.86	41,442	0.0141	333.0	0.01306	34	"
"	8	32,564	"	7.22	0.00250	30.5	55.17	44.81	6.46	3.98	44,397	0.0146	356.4	0.02505	37.5	"
"	9	35,226	"	7.53	0.00250	30.5	57.30	45.42	6.71	4.06	47,852	0.0144	384.5	0.03956	25	"
"	10	36,585	"	7.62	0.00250	29.5	58.52	46.61	6.77	4.07	48,769	0.0142	396.0	0.05312	30	"
"	11	37,945	"	7.80	0.00270	30.0	59.44	47.24	6.95	4.29	51,438	0.0148	413.1	0.05283	25	"
"	12	40,493	"	8.02	0.00250	30.2	61.57	46.94	7.04	4.15	54,122	0.0139	433.5	0.07689	23	"
"	13	40,974	"	8.02	0.00285	30.5	62.48	47.85	7.10	4.45	55,675	0.0147	443.6	0.08536	21	"
"	14	42,192	"	8.35	0.00260	30.5	61.57	47.55	7.38	4.34	56,981	0.0146	454.4	0.10045	23	Light Local Riffles
"	15	45,189	"	8.41	0.00260	30.3	61.26	48.16	7.44	4.36	56,949	0.0147	455.8	0.10045	23	"
"	16	44,741	"	8.29	0.00290	30.5	65.84	49.07	7.29	4.55	60,181	0.0143	480.0	0.17486	25	Local Riffles
"	17	45,675	"	8.32	0.00250	30.5	67.06	48.77	7.22	4.21	60,783	0.0129	484.2	0.18127	21	"
17m	2	10,109	81.92	2.62	0.00490	30.0	47.24	37.19	2.50	3.47	14,701	0.0127	118.1	0.00058	22	Smooth
"	3	11,978	"	2.99	0.00500	30.0	48.77	40.84	2.84	3.73	17,218	0.0135	138.5	0.00310	24	"
"	4	12,488	"	3.11	0.00500	29.5	49.07	42.98	2.96	3.81	17,869	0.0138	145.5	0.00471	23.4	"
"	5	13,196	"	3.17	0.00500	29.5	50.60	41.15	2.99	3.83	18,614	0.0135	151.3	0.01744	29	"
"	6	13,875	"	3.35	0.00430	30.0	50.60	43.59	3.14	3.64	19,780	0.0129	158.9	0.01058	28	"
"	7	14,470	"	3.29	0.00500	29.5	53.64	49.07	3.11	3.90	20,538	0.0130	166.8	0.03365	32.3	Local Riffles
"	8	15,178	"	3.32	0.00470	29.5	55.78	51.51	3.11	3.79	21,357	0.0122	173.5	0.04742	27.3	General Riffles Scouring
"	9	15,603	"	3.60	0.00480	30.0	53.04	49.99	3.38	3.99	22,345	0.0137	179.3	0.03977	27	"
"	10	15,603	"	3.66	0.00500	30.0	52.12	49.68	3.44	4.11	22,354	0.0144	179.3	0.05713	27	Local Riffles
"	11	17,302	"	3.90	0.00500	30.0	54.25	53.34	3.66	4.24	24,713	0.0143	198.6	0.09314	24.5	General Riffles Scouring
"	12	17,387	"	3.78	0.00485	29.5	56.08	49.07	3.54	4.10	24,421	0.0134	198.5	0.10500	20	General Riffles
"	13	19,369	"	4.08	0.00485	29.5	57.91	59.74	3.81	4.26	27,172	0.0136	220.6	0.10996	33	General Riffles Scouring
"	14	19,765	"	4.11	0.00480	29.5	58.52	58.52	3.84	4.25	27,674	0.0135	224.7	0.14634	21.5	"
"	15	20,983	"	4.30	0.00500	29.5	59.74	62.79	3.99	4.42	29,377	0.0138	238.4	0.16515	21	"
"	16	23,758	"	4.63	0.00500	29.5	62.79	61.57	4.30	4.59	33,235	0.0138	270.0	0.23150	20.5	"
17n	2	6,003	81.92	1.71	0.01010	28.5	42.67	31.39	1.68	4.08	8,648	0.0154	71.7	0.00294	21	Local Riffles
"	3	6,654	"	1.80	0.01000	28.5	45.11	32.92	1.74	4.13	9,475	0.0149	78.5	0.01608	20	General Riffles
"	4	7,079	"	1.89	0.00980	28.5	45.72	32.92	1.83	4.19	10,111	0.0150	83.7	0.01860	20	General Riffles Scouring
"	5	7,702	"	2.10	0.01000	28.5	44.50	42.67	2.04	4.47	10,988	0.0168	90.8	0.03080	20	"
"	6	7,787	"	2.04	0.01000	27.5	46.63	46.33	1.98	4.41	10,958	0.0157	92.3	0.04452	20	"
"	7	8,608	"	2.13	0.01000	28.5	49.38	46.94	2.07	4.51	12,378	0.0153	102.2	0.09797	20	"
"	8	9,231	"	2.26	0.01000	27.5	49.99	50.29	2.20	4.64	13,016	0.0157	110.0	0.12050	20	"
"	9	9,571	"	2.26	0.00980	27.5	51.82	52.73	2.20	4.60	13,493	0.0150	114.0	0.13208	22	"
"	10	10,137	"	2.44	0.01000	27.5	50.60	54.25	2.35	4.80	14,088	0.0162	118.9	0.18396	20	"
MATERIAL IV																
17o	4	14,611	81.92	4.88	0.00135	26.0	36.58	32.00	4.45	2.43	18,689	0.0126	162.8	0.00050	24	Smooth
"	5	16,254	"	5.15	0.00135	"	38.40	34.14	4.66	2.48	20,558	0.0124	178.9	0.00124	20	"
"	6	18,236	"	5.49	0.00135	"	40.54	35.05	4.91	2.55	22,839	0.0121	199.1	0.00248	20	"
"	7	19,878	"	5.79	0.00155	"	41.76	35.97	5.21	2.81	24,989	0.0132	217.6	0.00616	20	"
"	8	22,200	"	6.10	0.00180	"	44.50	37.49	5.52	3.12	28,187	0.0138	245.6	0.01414	20	"
"	9	24,013	"	6.34	0.00135	"	46.33	38.40	5.55	2.71	29,505	0.0115	257.1	0.02654	20	"
"	10	25,712	"	6.71	0.00175	"	46.94	40.23	6.01	3.21	32,362	0.0137	282.7	0.03307	28	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 36 (CONTINUED)
BED-LOAD EXPERIMENTS OF T. Y. LIU
IOWA INSTITUTE OF HYDRAULIC RESEARCH

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, $G^{(2)}$ grams per second per centimeter	Duration of run minutes	Bed condition
Page	Run Number						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
MATERIAL IV (CONTINUED)																
17o	11	27,411	81.92	6.86	0.00180	26.0	48.77	40.54	6.10	3.28	34,133	0.0135	297.5	0.04779	23.5	Smooth
"	12	30,072	"	7.32	0.00175	"	50.29	41.76	6.46	3.33	37,310	0.0134	324.9	0.08144	20	Dunes
"	13	31,233	"	7.56	0.00190	"	50.29	42.67	6.71	3.54	38,719	0.0143	337.4	0.12319	20	"
"	14	33,244	"	7.62	0.00200	"	53.34	45.72	6.74	3.64	41,251	0.0139	359.5	0.13580	20	"
"	15	35,538	"	8.14	0.00190	"	53.34	47.24	7.16	3.65	43,866	0.0141	381.9	0.17404	20.5	"
17p	3	12,091	81.92	3.93	0.00180	25.5	37.49	35.36	3.63	2.53	15,452	0.0124	136.1	0.00186	20	Smooth
"	4	13,366	"	4.02	0.00210	"	40.54	36.58	3.72	2.77	17,133	0.0126	150.8	0.00517	21.5	"
"	5	15,093	"	4.27	0.00240	"	43.28	38.71	3.96	3.05	19,486	0.0132	171.4	0.01174	20	"
"	6	16,537	"	4.54	0.00235	"	44.50	39.32	4.18	3.10	21,117	0.0131	186.0	0.02530	20	"
"	7	18,236	"	4.79	0.00240	"	46.63	40.23	4.39	3.21	23,257	0.0131	204.7	0.04667	22	"
"	8	18,632	"	4.88	0.00240	"	46.63	43.59	4.48	3.25	23,744	0.0133	208.9	0.04936	20	"
"	9	20,360	"	5.06	0.00250	"	49.07	43.28	4.63	3.37	25,834	0.0132	227.2	0.06304	20	Light Dunes
"	10	21,946	"	5.46	0.00250	26.0	49.07	44.81	4.97	3.49	27,988	0.0138	243.9	0.09632	20	"
"	11	22,569	"	5.49	0.00250	"	50.29	44.50	5.00	3.50	28,863	0.0135	251.5	0.09756	20	"
"	12	23,928	"	5.61	0.00250	"	52.12	44.81	5.09	3.53	30,458	0.0132	265.3	0.11678	29	"
"	13	24,975	"	5.85	0.00250	"	52.12	45.42	5.30	3.60	31,739	0.0136	276.2	0.12732	26	"
"	14	25,938	"	5.91	0.00250	"	53.64	46.33	5.33	3.61	32,849	0.0132	285.9	0.13034	25	Dunes
"	15	28,034	"	6.25	0.00250	"	54.56	46.94	5.61	3.71	35,129	0.0134	306.1	0.15791	20	"
"	16	29,450	"	6.40	0.00250	25.5	56.08	48.16	5.73	3.75	36,516	0.0132	321.3	0.19781	28	"
17q	4	4,842	81.92	1.77	0.00505	26.0	33.53	35.36	1.71	2.91	6,571	0.0140	57.3	0.00248	20	Local Riffles
"	5	6,739	"	2.10	0.00505	"	39.01	38.10	2.04	3.18	9,146	0.0136	79.6	0.00930	20	General Riffles
"	6	7,419	"	2.23	000500	"	40.84	39.01	2.13	3.24	10,006	0.0135	87.0	0.02096	20	"
"	7	7,702	"	2.23	0.00500	"	42.37	39.93	2.13	3.24	10,381	0.0129	90.2	0.03138	20	"
"	8	8,269	"	2.23	0.00490	"	45.42	42.67	2.13	3.20	11,128	0.0119	96.7	0.04064	20	"
"	9	9,401	"	2.71	0.00490	"	42.37	43.89	2.59	3.53	12,604	0.0145	109.7	0.06407	20	"
"	10	9,996	"	2.68	000490	"	45.42	44.20	2.56	3.51	13,350	0.0134	116.3	0.06532	20	"
"	11	10,845	"	2.68	0.00500	"	49.38	45.11	2.53	3.52	14,343	0.0123	124.9	0.07768	20	"
"	12	11,610	"	2.93	0.00490	"	48.46	46.33	2.77	3.65	15,434	0.0133	134.2	0.10252	20	General Riffles Flattened
"	13	12,743	"	2.90	0.00500	"	53.64	49.07	2.71	3.65	16,708	0.0119	145.4	0.12154	20	"
"	14	13,592	"	3.02	0.00500	25.5	55.17	50.60	2.84	3.73	17,774	0.0119	156.7	0.14493	20	"
"	15	14,385	"	3.20	0.00500	25.5	54.86	51.21	3.02	3.85	18,814	0.0125	165.7	0.16577	20	"
17r	2	2,180	81.92	0.91	0.01000	26.5	28.96	28.65	0.91	2.99	3,074	0.0151	26.4	0.00368	20	Local Riffles
"	3	2,662	"	0.94	0.00990	27.0	34.44	33.22	0.91	2.97	3,695	0.0126	31.3	0.02129	22	Local Riffles Scouring
"	4	3,143	"	1.07	0.00980	26.5	35.97	31.09	1.04	3.16	4,328	0.0131	37.4	0.00492	20	General Riffles
"	5	3,483	"	1.16	0.00950	27.0	36.88	32.31	1.13	3.24	4,883	0.0133	41.7	0.01232	20	"
"	6	3,596	"	1.16	0.00880	"	38.10	36.27	1.13	3.12	5,044	0.0124	43.1	0.03200	20	"
"	7	4,191	"	1.34	0.00940	"	38.10	38.40	1.31	3.47	5,863	0.0141	49.9	0.03886	20	General Riffles Flattened
"	8	5,324	"	1.49	0.00990	"	43.28	40.84	1.46	3.76	7,432	0.0138	63.2	0.08826	20	"
"	9	5,550	"	1.25	0.00920	"	54.25	39.92	1.19	3.28	7,571	0.0093	64.6	0.07648	20	"
"	10	6,440	"	1.80	0.00970	"	43.28	41.76	1.74	4.07	8,824	0.0153	75.3	0.18520	20	"
MATERIAL V																
17s	2	42,277	81.92	9.17	0.00240	23.0	56.08	43.28	8.17	4.38	49,260	0.0165	458.2	0.00050	25	Smooth
"	3	47,855	"	10.06	0.00260	"	57.91	47.85	8.96	4.78	55,799	0.0176	518.9	0.00103	23.5	"
"	4	53,745	"	10.52	0.00225	"	62.48	51.21	9.11	4.48	61,230	0.0154	569.2	0.00157	23.5	"
"	5	58,899	"	11.22	0.00185	"	64.01	51.82	9.39	4.13	64,616	0.0139	601.1	0.00211	23.5	"
"	6	63,713	"	11.58	0.00180	"	67.06	52.43	9.51	4.10	68,574	0.0132	637.7	0.00322	23	"
17t	5	28,798	81.92	6.52	0.00270	22.5	53.95	43.89	5.91	3.96	33,829	0.0146	318.8	0.00050	24	"
"	6	32,593	"	7.10	0.00290	"	56.08	43.89	6.43	4.28	38,245	0.0154	360.6	0.00050	25	"
"	7	37,661	"	7.62	0.00335	"	60.35	46.33	6.89	4.76	44,082	0.0161	415.8	0.00107	23	"
"	8	42,022	"	8.23	0.00310	"	62.18	46.94	7.38	4.74	48,636	0.0157	458.9	0.00165	30	"
"	9	45,109	"	8.50	0.00300	"	64.62	49.07	7.53	4.71	51,593	0.0151	486.6	0.00223	22	"
"	10	48,507	"	9.08	0.00270	"	65.23	51.51	7.96	4.59	55,027	0.0147	519.2	0.00227	32.5	"
"	11	49,130	"	9.11	0.00260	"	65.84	54.25	7.93	4.50	55,332	0.0143	522.1	0.00500	27	"
"	12	51,650	"	9.81	0.00250	"	64.31	55.47	8.53	4.57	58,200	0.0151	548.6	0.00690	25	"
"	13	53,859	"	9.45	0.00265	"	69.49	58.22	8.14	4.60	59,969	0.0139	565.6	0.02199	23	"
"	14	57,766	"	10.36	0.00260	"	67.97	59.44	8.96	4.78	64,590	0.0150	609.1	0.02236	27	"
"	15	63,883	"	10.88	0.00275	"	71.63	57.91	9.33	5.02	70,848	0.0151	668.3	0.03489	23	"
17u	5	19,765	81.92	4.22	0.00510	24.0	54.56	44.50	4.15	4.56	24,852	0.0157	226.4	0.00099	25	"
"	6	22,455	"	4.66	0.00500	"	58.52	49.68	4.36	4.62	28,032	0.0150	255.1	0.00198	25	"
"	7	25,910	"	5.24	0.00500	"	60.35	51.21	4.88	4.89	32,344	0.0157	294.5	0.00558	20	"
"	8	28,034	"	5.33	0.00540	"	64.01	52.43	4.94	5.11	34,734	0.0155	316.2	0.00864	20	"
"	9	30,894	"	5.61	0.00533	22.5	67.06	54.25	5.18	5.21	36,851	0.0152	347.4	0.01496	24	"
"	10	34,575	"	6.07	0.00510	"	69.49	55.78	5.55	5.27	40,876	0.0150	385.7	0.03142	22	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 36 (CONTINUED)
BED-LOAD EXPERIMENTS OF T. Y. LIU
IOWA INSTITUTE OF HYDRAULIC RESEARCH

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, $G^{(2)}$ grams per second per centimeter	Duration of run minutes	Bed condition
Page	Run Number						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
MATERIAL V (CONTINUED)																
17u	11	36,897	81.92	6.49	0.00500	225	69.49	57.91	5.91	5.38	43,573	0.0155	410.7	0.03654	25	Smooth
"	12	40,578	"	6.80	0.00500	"	72.85	59.44	6.16	5.50	47,565	0.0151	448.8	0.06912	225	"
"	13	43,325	"	7.07	0.00500	"	74.68	61.57	6.40	5.60	50,692	0.0152	478.0	0.10541	28	"
"	14	47,204	"	7.41	0.00460	"	77.72	63.09	6.58	5.45	54,264	0.0142	511.4	0.13931	23	"
"	15	49,554	"	7.62	0.00480	"	79.55	66.14	6.80	5.66	57,338	0.0145	540.9	0.17238	23	"
17v	3	10,902	81.92	2.53	0.01000	24.5	52.73	38.71	2.44	4.89	14,300	0.0159	128.7	0.00062	20	"
"	4	11,610	"	2.53	0.01000	"	56.08	44.20	2.44	4.89	15,208	0.0150	136.8	0.00099	25	"
"	5	13,054	"	2.77	0.01000	"	57.30	46.33	2.65	5.10	16,903	0.0155	151.8	0.00236	21	"
"	6	13,507	"	2.83	0.01000	"	58.22	47.55	2.71	5.16	17,570	0.0155	157.8	0.00434	20	"
"	7	14,045	"	2.96	0.01000	"	57.91	48.46	2.84	5.28	18,262	0.0160	164.5	0.00504	22	"
"	8	15,291	"	3.05	0.01000	"	61.26	49.38	2.93	5.36	19,938	0.0155	179.5	0.01480	20	"
"	9	16,084	"	3.14	0.00970	"	62.48	50.60	2.99	5.33	20,759	0.0152	186.8	0.03022	20	"
"	10	17,075	"	3.35	0.01000	"	62.18	51.82	3.20	5.60	22,133	0.0162	199.0	0.04754	20	Local Riffles
"	11	17,217	"	3.32	0.01000	"	63.09	53.04	3.17	5.58	22,246	0.0159	200.0	0.05498	22	"
"	12	18,010	"	3.44	0.01000	"	63.70	54.25	3.29	5.68	23,326	0.0161	209.6	0.06283	20	"
"	13	19,199	"	3.57	0.01000	"	65.53	55.78	3.38	5.76	24,659	0.0160	221.5	0.10376	25	Local Riffles Scouring
"	14	19,539	"	3.47	0.01000	"	68.58	56.69	3.29	5.68	25,113	0.0150	225.6	0.10922	20	General Riffles
"	15	20,303	"	3.78	0.01000	"	65.23	57.61	3.60	5.94	26,099	0.0167	234.8	0.13642	20	"
"	16	21,408	"	3.96	0.01000	"	65.84	57.91	3.78	6.09	27,684	0.0171	248.9	0.19884	20	General Riffles Scouring
MATERIAL VI																
17w	4	18,066	81.92	5.49	0.00165	26.5	40.23	32.00	5.00	2.84	23,331	0.0135	201.2	0.00041	30	Smooth
"	5	19,709	"	5.79	0.00170	"	41.45	33.53	5.27	2.96	25,356	0.0140	218.4	0.00124	30	"
"	6	21,662	"	6.10	0.00195	"	43.28	33.83	5.58	3.27	28,006	0.0149	241.5	0.00186	20	"
"	7	23,843	"	6.37	0.00185	"	45.72	35.66	5.76	3.23	30,556	0.0140	263.3	0.00372	20	"
"	8	25,230	"	6.68	0.00180	"	46.02	36.58	6.01	3.26	32,059	0.0141	276.6	0.00740	20	"
"	9	27,439	"	6.98	0.00190	"	47.85	37.80	6.25	3.41	34,683	0.0144	299.1	0.01505	23	"
"	10	29,308	"	7.22	0.00190	"	49.68	39.62	6.43	3.46	37,064	0.0141	319.4	0.02406	20	"
"	11	31,998	"	7.59	0.00235	"	51.51	40.84	6.86	3.98	40,981	0.0158	353.3	0.03291	21	"
"	12	33,131	"	7.86	0.00235	"	51.51	42.06	7.10	4.05	42,439	0.0162	365.8	0.04940	20	"
"	13	35,396	"	7.92	0.00225	"	54.56	43.28	7.04	3.94	44,566	0.0148	384.1	0.09012	20	Light Dunes
"	14	37,945	"	8.38	0.00225	"	55.17	43.59	7.44	4.05	47,599	0.0152	410.5	0.12960	20	Dunes
"	15	39,983	"	8.56	0.00235	"	57.00	45.72	7.59	4.18	50,189	0.0153	432.6	0.14944	20	"
"	16	40,776	"	9.17	0.00220	"	54.25	46.94	8.17	4.20	51,412	0.0163	443.2	0.19429	20	"
17x	3	12,629	81.92	3.99	0.00245	27.0	38.71	31.39	3.75	3.00	17,033	0.0143	145.2	0.00041	30	Smooth
"	4	14,895	"	4.27	0.00250	"	42.67	33.53	3.96	3.12	19,843	0.0136	169.0	0.00124	20	"
"	5	15,942	"	4.63	0.00245	"	42.06	35.05	4.30	3.21	21,218	0.0144	180.9	0.00372	20	"
"	6	17,840	"	4.88	0.00245	"	44.50	36.88	4.51	3.29	23,561	0.0141	200.7	0.00492	20	"
"	7	19,624	"	5.18	0.00250	"	46.33	38.10	4.76	3.42	25,857	0.0142	220.5	0.00823	27	"
"	8	21,577	"	5.46	0.00250	"	48.16	39.01	5.00	3.50	28,257	0.0141	240.8	0.00984	20	"
"	9	23,475	"	5.73	0.00250	"	49.99	41.76	5.24	3.58	30,763	0.0140	261.9	0.02402	20	"
"	10	26,250	"	6.04	0.00250	26.5	53.04	43.89	5.46	3.66	33,571	0.0136	289.6	0.03642	22	"
"	11	27,439	"	6.37	0.00240	"	52.73	45.72	5.73	3.67	35,051	0.0138	302.1	0.08789	35	"
"	12	29,506	"	6.49	0.00250	"	55.47	46.63	5.82	3.78	37,465	0.0135	322.8	0.10913	20	Dunes
"	13	31,432	"	6.61	0.00250	"	57.91	46.94	5.88	3.80	39,523	0.0131	340.5	0.12360	20	"
"	14	32,736	"	6.89	0.00250	"	57.91	47.55	6.13	3.88	41,155	0.0134	355.0	0.16205	20	"
17y	3	6,994	81.92	2.35	0.00500	23.5	36.27	32.61	2.26	3.33	8,894	0.0156	82.0	0.00207	30	Smooth
	4	7,702	"	2.41	0.00500	23.5	39.01	32.61	2.32	3.37	9,820	0.0148	90.5	0.00165	30	"
	5	8,665	"	2.44	0.00500	24.0	43.28	34.14	2.35	3.39	11,162	0.0134	101.7	0.00455	20	"
	6	8,778	"	2.50	0.00500	"	42.67	36.58	2.41	3.44	11,291	0.0138	102.8	0.00744	30	"
	7	9,033	"	2.59	0.00500	"	42.37	36.58	2.47	3.48	11,496	0.0142	104.7	0.01112	20	"
	8	10,052	"	2.71	0.00500	"	45.42	37.80	2.59	3.56	12,932	0.0136	117.6	0.02046	20	Local Riffles
	9	11,015	"	2.83	0.00500	"	47.55	41.76	2.68	3.62	14,014	0.0134	127.4	0.02960	20	"
	10	11,553	"	3.05	0.00500	"	46.63	42.67	2.90	3.77	14,840	0.0143	135.2	0.04936	21	General Riffles
	11	12,488	"	3.14	0.00500	"	48.46	46.33	2.99	3.83	15,907	0.0141	144.9	0.06945	24	"
	12	13,366	"	3.14	0.00500	"	51.82	47.55	2.96	3.81	16,839	0.0131	153.4	0.10368	20	"
	13	14,187	"	3.41	0.00450	23.5	50.90	47.55	3.20	3.76	17,704	0.0133	162.9	0.10872	22	Light Dunes
	14	15,942	"	3.47	0.00480	"	55.78	48.77	3.26	3.92	19,772	0.0127	181.8	0.17032	20	"
17z	2	3,653	81.92	1.19	0.00990	23.5	37.49	29.87	1.16	3.36	4,719	0.0136	43.5	0.00207	30	Local Riffles
	3	5,097	"	1.52	0.01000	"	40.54	34.44	1.49	3.82	6,583	0.0150	60.4	0.01852	22	General Riffles
	4	5,465	"	1.62	0.01000	24.0	41.15	33.83	1.59	3.95	7,167	0.0154	65.4	0.01724	20	"
	5	5,720	"	1.77	0.00970	"	39.32	38.10	1.74	4.07	7,505	0.0168	68.4	0.03700	21	"
	6	6,173	"	1.80	0.01000	"	41.76	38.40	1.77	4.17	8,113	0.0163	73.9	0.04816	20	"
	7	6,173	"	1.74	0.01000	"	43.28	38.20	1.71	4.09	8,119	0.0153	74.0	0.06594	20	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 36 (CONTINUED)
BED-LOAD EXPERIMENTS OF T. Y. LIU
IOWA INSTITUTE OF HYDRAULIC RESEARCH

Author's references							Velocity centimeters per second									
Page (1)	Run Number (2)	Discharge, Q cubic centimeters per second (3)	Width of flume, B centimeters (4)	Mean water depth, D centimeters (5)	Water surface slope, S (6)	Water temperature degrees centigrade (7)	Mean V_m (8)	Bottom V_b (9)	Hydraulic radius of bed, r_b centimeters (10)	Friction velocity, V^* centimeters per second (11)	Reynolds Number, R (12)	Manning's n of bed, n_b (1) (13)	Unit discharge, q_b cubic centimeters per second per centimeter (14)	Rate of bed movement, G (2) grams per second per centimeter (15)	Duration of run minutes (16)	Bed condition (17)
MATERIAL VI (CONTINUED)																
173	8	6,909	81.92	1.83	0.01000	24.0	46.02	41.76	1.77	4.17	8,941	0.0148	81.5	0.10128	20.5	General Riffles
"	9	7,702	"	1.83	0.01000	"	51.51	44.81	1.77	4.17	10,008	0.0132	91.2	0.14386	20	"
"	10	9,090	"	2.13	0.01000	"	52.12	47.85	2.07	4.51	11,873	0.0145	107.9	0.24700	20	Riffles Flattened Scouring

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(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 37
BED-LOAD EXPERIMENTS OF J. BOGARDI AND C. H. YEN
IOWA INSTITUTE OF HYDRAULIC RESEARCH

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, $G^{(2)}$ grams per second per centimeter	Duration of run minutes	Bed condition
Table	Run Number						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
MATERIAL I																
6	5	42,305	83.82	5.21	0.0232	11.0	99.06	51.21	4.97	10.63	38,659	0.0208	492.3	0.04349		Fairly Smooth
"	7	41,484	"	5.91	0.0243	9.5	85.65	48.16	5.70	11.65	36,707	0.0270	488.2	0.15502		Scoured
"	8	43,608	"	6.04	0.0248	10.0	88.09	59.74	5.82	11.90	39,150	0.0270	512.9	0.24266		"
"	10	37,945	"	5.36	0.0242	13.0	85.95	–	5.18	11.09	36,931	0.0252	445.2	0.05539		Fairly Smooth
"	13	54,425	"	7.80	0.0190	13.8	84.73	51.21	7.47	11.80	53,579	0.0288	632.9	0.04303		" "
"	15	62,354	"	8.87	0.0205	14.0	85.34	48.77	8.50	13.08	61,764	0.0325	725.4	0.17342		Smooth
"	17	57,058	"	8.26	0.0208	14.0	84.12	55.78	7.93	12.71	56,736	0.0316	667.1	0.06449		Lightly Scoured
"	19	58,899	"	8.63	0.0176	14.5	83.52	56.69	8.26	11.94	59,523	0.0301	689.9	0.06155	Not Recorded	" "
"	21	58,050	"	8.29	0.0177	15.0	85.04	57.91	7.96	11.75	59,238	0.0289	676.9	0.05101		Smooth
"	22	61,589	"	9.20	0.0175	15.0	81.38	50.29	8.81	12.30	62,774	0.0322	717.0	0.05192		Scoured
"	23	61,306	"	8.87	0.0175	14.5	84.12	57.91	8.47	12.06	61,497	0.0303	712.5	0.09868		"
"	25	63,854	"	9.24	0.0177	14.8	84.12	56.69	8.84	12.39	64,655	0.0314	743.6	0.15006		"
"	35	64,223	"	8.96	0.0176	17.0	87.17	57.91	8.53	12.14	68,500	0.0295	743.6	0.10996		"
"	41	49,526	"	7.04	0.0190	17.0	85.65	58.22	6.74	11.20	53,125	0.0267	577.3	0.05705		Lightly Scoured
"	43	55,359	"	7.56	0.0194	17.0	89.00	60.96	7.22	11.72	59,202	0.0272	642.6	0.19719		Scoured
"	48	46,666	"	6.28	0.0218	17.2	90.53	61.57	6.01	11.33	50,336	0.0250	544.1	0.23522		"
7	129	22,512	30.48	7.04	0.0200	19.6	106.07	–	5.94	10.79	62,201	0.0203	630.1	0.75815		"
"	133	19,822	"	8.38	0.0155	19.3	78.64	52.73	7.37	10.58	56,824	0.0278	579.6	0.03249		Scoured rough
"	135	29,025	"	9.60	0.0119	19.1	100.89	50.60	7.55	9.39	74,167	0.0193	761.7	0.01344		Rough
"	136	40,210	"	12.92	0.0132	19.2	103.63	54.56	10.26	11.52	103,930	0.0243	1063.2	0.05581		Scoured
MATERIAL II																
8	56	30,724	83.82	5.06	0.0148	19.0	74.37	46.63	4.85	8.39	34,956	0.0217	360.7	0.01199		Fairly Smooth
"	57	22,880	"	4.02	0.0143	19.0	69.19	45.11	3.90	7.40	26,179	0.0197	269.9	0.00182		Smooth
"	59	43,750	"	6.28	0.0158	19.0	84.43	47.85	5.97	9.62	48,922	0.0227	504.0	0.21641		Scoured
"	61	30,469	"	4.69	0.0172	19.0	78.94	50.90	4.51	8.72	34,539	0.0211	356.0	0.03291		Fairly Smooth
"	63	36,953	"	5.36	0.0177	19.2	83.52	50.90	5.12	9.43	41,809	0.0220	427.6	0.18912		Scoured
"	67	25,768	"	4.02	0.0199	20.0	78.03	48.46	3.87	8.69	30,205	0.0207	302.0	0.03059		Fairly Smooth
"	69	25,712	"	3.99	0.0197	20.0	78.33	51.21	3.84	8.61	30,079	0.0204	300.8	0.02658	Not Recorded	Scoured
"	71	36,444	"	5.00	0.0202	20.0	88.70	54.86	4.79	9.74	42,443	0.0211	424.9	0.41504		Generally Scoured
"	73	25,259	"	3.87	0.0198	20.0	79.55	50.60	3.72	8.50	29,585	0.0197	295.9	0.02637		Fairly Smooth
"	77	25,995	"	3.93	0.0229	20.0	80.47	51.82	3.81	9.25	30,659	0.0213	306.6	0.24431		Scoured
"	79	21,153	"	3.51	0.0223	20.0	73.46	47.55	3.41	8.64	25,079	0.0214	250.5	0.03811		Generally Scoured
"	82	22,652	"	3.57	0.0228	19.5	78.33	52.43	3.44	8.78	26,578	0.0204	269.5	0.06242		Scoured
"	87	42,164	"	6.16	0.0155	19.9	83.21	50.60	5.85	9.43	48,452	0.0226	486.8	0.05634		Fairly Smooth
"	89	49,781	"	7.38	0.0145	19.8	82.30	54.25	7.01	9.98	57,234	0.0249	576.9	0.21909		Heavily Scoured
"	91	35,821	"	5.55	0.0153	19.8	78.33	52.43	5.30	8.92	41,216	0.0223	415.1	0.01761		Smooth
"	92	43,183	"	6.16	0.0159	19.6	85.34	52.12	5.85	9.55	49,300	0.0223	499.2	0.06283		Rough
9	150	27,467	30.48	8.66	0.0109	21.6	105.46	58.83	6.54	8.36	71,546	0.0161	689.7	0.24100		Scoured
"	152	15,659	"	5.67	0.0141	21.6	92.35	49.07	4.73	8.09	45,311	0.0168	436.8	0.06135		Rough
MATERIAL III																
10	97	65,922	30.48	19.66	0.0114	22.0	111.86	70.41	14.60	12.78	171,011	0.0265	1633.2	0.03001		Rough
"	104	47,289	"	13.62	0.0143	22.5	115.52	61.87	10.52	12.14	128,824	0.0231	1215.3	0.01075		"
"	107	51,395	"	13.75	0.0125	21.8	123.75	67.97	9.91	11.02	127,828	0.0194	1226.4	0.05233	Not Recorded	"
"	108	49,271	"	12.98	0.0112	21.0	126.49	72.85	8.90	9.89	115,108	0.0167	1125.8	0.09111		"
"	113	38,568	"	10.30	0.0160	21.2	124.66	72.85	7.89	11.13	101,241	0.0187	983.6	0.10194		Scoured
"	115	45,590	"	11.43	0.0186	20.8	132.59	82.91	8.81	12.68	118,818	0.0204	1168.1	0.21537		"
"	120	31,460	"	8.56	0.0186	19.6	122.53	71.92	6.83	11.16	82,590	0.0186	836.9	0.10781		Generally Scoured
"	122	39,191	"	9.42	0.0209	19.8	138.07	-	7.32	12.24	100,197	0.0183	1010.7	0.92268		Heavily Scoured
"	124	33,131	"	9.05	0.0177	19.8	122.83	75.59	7.13	11.13	86,907	0.0187	875.8	0.20669		Generally Scoured
"	125	25,032	"	7.22	0.0195	20.0	115.52	65.53	7.10	11.65	82,042	0.0208	820.2	0.02245		Rough

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 38
BED-LOAD EXPERIMENTS OF M. P. O'BRIEN
UNIVERSITY OF CALIFORNIA

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Slope of energy gradient, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, $G^{(2)}$ grams per second per centimeter	Duration of run minutes	Bed condition
Table (1)	Run Number (2)	(3)	(4)	(5)	(6)	(7)	Mean V_m (8)	Bottom V_b (9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
							COLUMBIA RIVER SAND									
I&II	3-B	19,595	91.44	8.93	0.00115		24.02	No Observations	8.57	3.11	19,955	0.0274	205.9	0.00430	228	No Observations
"	3-C	18,972	"	9.20	0.00149		22.49		8.93	3.61	19,482	0.0344	200.8	0.00707		
"	4-A	24,834	"	9.63	0.00202		28.25		9.30	4.29	25,447	0.0327	262.7	0.02381	78	
"	4-B	24,579	"	9.14	0.00083	18.9	29.47		8.47	2.63	24,196	0.0189	249.6	0.02112	457	
"	4-C	24,551	"	9.97	0.00151		27.04		9.57	3.76	25,078	0.0301	258.8	0.02042		
"	5-A	31,432	"	10.27	0.00176		33.47		9.75	4.10	32,069	0.0266	326.3	0.08764		
"	5-B	31,432	"	9.66	0.00063	19.4	36.57		8.53	2.30	30,657	0.0137	311.9	0.11699	159	
"	5-C	31,432	"	10.27	0.00186		36.52		9.72	4.21	34,881	0.0250	355.0	0.07069		
"	6-A	37,095	"	10.73	0.00169		37.64		10.09	4.09	35,758	0.0236	379.8	0.15626		
"	6-B	37,945	"	11.03	0.00261	17.8	37.83		10.55	5.20	37,566	0.0301	399.1	0.13972	120	
"	6-C	38,228	"	11.16	0.00230		37.49		10.64	4.90	37,554	0.0288	398.9	0.06614		
"	7-A	43,042	"	11.70	0.00158		39.72		10.88	4.11	40,317	0.0228	432.2	0.12402	123	
"	7-B	40,776	"	11.09	0.00152		40.20		10.30	3.92	38,633	0.0214	414.1	0.17197		
"	7-C	43,042	"	10.97	0.00227		42.92		10.33	4.80	41,371	0.0245	443.4	0.23646		
"	8-A	57,483	"	11.52	0.00308	17.2	54.59		10.76	5.70	54,383	0.0230	587.4	0.65315	50	
"	8-B	57,483	"	11.61	0.00230		54.16		10.64	4.90	53,348	0.0199	576.3	0.65315		
"	9-A	42,475	"	11.73	0.00263	18.3	39.59		11.19	5.37	42,257	0.0301	443.0	0.09921	90	
"	9-B	42,475	"	10.91	0.00114		42.58		9.85	3.32	40,000	0.0169	419.4	0.12567		
"	9-C	42,475	"	10.30	0.00131		45.08		9.33	3.46	40,120	0.0165	420.6	0.23439		
"	9-D	42,475	"	10.73	0.00092		43.28		9.48	2.92	39,146	0.0147	410.3	0.20752		
"	10-A	37,661	"	9.72	0.00155	17.8	42.34		8.96	3.69	35,726	0.0186	379.4	0.21000	120	
"	11-A	31,149	"	9.66	0.00165	17.2	35.30		9.11	3.84	29,789	0.0233	321.6	0.09880	127	
"	11-B	31,149	"	10.52	0.00115		32.43		9.85	3.33	29,562	0.0224	319.4	0.09880		
"	11-C	31,432	"	11.43	0.00323		30.08		11.13	5.94	30,985	0.0437	334.8	0.09880		
"	12-A	26,618	"	8.99	0.00138	15.0	32.34		8.47	3.39	23,994	0.0222	273.9	0.05333	349	
"	12-B	26,618	"	8.93	0.00146		32.55		8.44	3.48	24,065	0.0226	274.7	0.05250		
"	12-C	26,618	"	8.84	0.00215		32.89		8.47	4.15	24,403	0.0272	278.6	0.04754		
"	13-A	23,361	"	9.36	0.00169	15.0	27.31		9.02	3.87	21,575	0.0303	246.3	0.01240	415	
"	13-B	23,361	"	9.33	0.00146		27.40		8.93	3.58	21,428	0.0279	244.7	0.02691		
"	13-C	23,361	"	9.33	0.00208		27.40		9.02	4.29	21,646	0.0335	247.1	0.02468		
"	15-A	19,114	"	9.75	0.00057		21.43		9.17	2.26	15,715	0.0227	196.5	0.00356	215	
"	15-B	19,114	"	9.63	0.00069	11.6	21.70		9.14	2.49	15,861	0.0246	198.3	0.00447		
"	15-C	19,114	"	9.54	0.00094		21.92		9.14	2.90	16,022	0.0284	200.3	0.00847		
"	16-B	101,374	"	30.78	0.00086		35.91		27.89	4.85	80,962	0.0348	1001.5	0.00207	172	
"	16-C	99,392	"	31.27	0.00089		34.75		28.23	4.96	79,287	0.0370	980.6	0.00207		
"	16-D	99,392	"	31.27	0.00086		34.75		28.47	4.90	79,973	0.0365	989.3	0.00207		
"	17-A	126,293	"	31.88	0.00087		43.40		27.95	4.88	99,266	0.0290	1213.0	0.04217		
"	17-B	126,293	"	30.82	0.00114	12.5	44.93		27.55	5.55	101,309	0.0319	1237.8	0.04217	169	
"	17-C	124,877	"	30.97	0.00107		44.10		27.62	5.38	99,658	0.0304	1218.0	0.05498		
"	19-B	112,418	"	31.67	0.00055	11.1	38.71		27.04	3.82	82,537	0.0253	1046.7	0.00496	309	
"	19-C	112,418	"	31.94	0.00050		38.40		26.98	3.64	81,691	0.0243	1036.0	0.01265		
"	19-E	112,418	"	31.73	0.00050		38.65		26.73	3.62	81,479	0.0240	1033.1	0.01265		
"	19-F	112,418	"	32.55	0.00029		37.67		25.12	2.67	74,615	0.0180	946.3	0.01802		
"	19-G	111,568	"	31.73	0.00075		38.34		28.10	4.55	84,974	0.0306	1077.4	0.01802		
"	19-H	111,002	"	31.85	0.00046		38.22		26.64	3.47	80,298	0.0232	1018.2	0.01802		
"	19-I	110,436	"	32.37	0.00055		37.31		27.89	3.88	82,061	0.0268	1040.6	0.01802		
"	20-A	152,628	"	31.91	0.00067	11.1	52.12		25.60	4.10	105,239	0.0200	1334.3	0.10789	106	
"	20-B	151,495	"	31.61	0.00031		52.61		20.30	2.50	85,110	0.0117	1079.0	0.10789		
"	20-C	150,079	"	31.73	0.00057		51.82		24.72	3.72	101,020	0.0182	1281.0	0.10789		
"	20-D	150,079	"	31.61	0.00047		52.03		23.50	3.29	96,428	0.0159	1222.7	0.10913		
"	20-E	150,079	"	31.70	0.00094		51.88		26.88	4.98	109,991	0.0247	1394.5	0.10789		
"	21-A	140,735	"	31.73	0.00075	11.4	48.62		26.55	4.42	102,523	0.0233	1290.9	0.10748	182	
"	21-B	139,885	"	32.00	0.00079		47.88		27.07	4.58	102,932	0.0245	1296.1	0.06408		
"	21-C	139,885	"	31.82	0.00047		48.16		24.54	3.36	93,857	0.0177	1181.8	0.06408		
"	21-D	139,036	"	31.46	0.00081		48.43		26.64	4.60	102,476	0.0243	1290.2	0.06408		
"	21-E	138,753	"	31.55	0.00062		48.01		25.70	3.95	97,984	0.0210	1233.9	0.06408		
"	21-F	139,036	"	31.21	0.00050		48.83		24.29	3.45	94,220	0.0179	1186.1	0.08185		
"	22-A	118,931	"	31.67	0.00062	11.7	41.06		27.04	4.05	88,808	0.0253	1110.3	0.01728	348	
"	22-B	118,931	"	32.31	0.00066		40.26		27.95	4.25	90,021	0.0273	1125.3	0.02336		
"	22-C	118,931	"	31.79	0.00079		40.90		27.92	4.65	91,354	0.0293	1141.9	0.02336		
"	22-D	116,665	"	31.79	0.00066		40.05		27.52	4.22	88,184	0.0271	1102.2	0.02336		
"	22-E	118,931	"	31.58	0.00054		41.18		26.43	3.74	87,058	0.0232	1088.4	0.02336		
"	22-F	118,931	"	32.13	0.00057		40.48		27.22	4.03	88,146	0.0248	1101.9	0.02336		

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 38 (CONTINUED)
BED-LOAD EXPERIMENTS OF M. P. O'BRIEN
UNIVERSITY OF CALIFORNIA

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Slope of energy gradient, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
Table	Run Number						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
COLUMBIA RIVER SAND (CONTINUED)																
I & II	22-G	116,665	91.44	31.97	0.00050		39.81	No Observations	26.73	3.62	85,133	0.0233	1064.1	0.03216		No Observations
"	23-A	102,507	"	32.71	0.00033	11.7	34.38		26.82	2.95	73,771	0.0220	922.1	0.00537	439	
"	23-B	103,357	"	31.70	0.00047		35.75		27.07	3.53	77,409	0.0254	967.8	0.00761		
"	23-C	102,507	"	32.31	0.00044		34.81		27.55	3.45	76,732	0.0256	959.0	0.00761		
"	23-D	102,507	"	32.10	0.00043		35.02		27.22	3.39	76,257	0.0249	953.2	0.00761		
"	23-E	102,507	"	31.58	0.00057		35.60		27.58	3.93	78,559	0.0284	981.8	0.00761		
"	23-F	102,507	"	31.70	0.00043		35.45		26.82	3.36	76,067	0.0243	950.8	0.00835		
"	23-G	102,507	"	31.91	0.00029		35.23		25.39	2.69	71,559	0.0194	894.5	0.00835		
"	26-A	107,038	"	15.82	0.00167	10.0	74.01		13.14	4.64	74,219	0.0143	972.5	1.03760	40	
"	26-B	105,339	"	15.82	0.00200		72.82		13.51	5.15	75,116	0.0162	983.8	1.03760		
"	27-A	85,800	"	16.06	0.00150	9.4	58.43		13.99	4.54	61,323	0.0179	817.4	0.39726	56	
"	27-B	84,667	"	16.37	0.00273		56.60		15.09	6.36	64,065	0.0262	854.1	0.48780		
"	27-C	84,667	"	16.15	0.00079		57.33		12.89	3.16	55,450	0.0125	739.0	0.47953		
"	28-A	61,448	"	15.61	0.00134	8.9	43.04		14.23	4.32	45,313	0.0232	612.5	0.11037	141	
"	28-B	61,448	"	16.06	0.00134		41.82		14.69	4.39	45,442	0.0244	614.3	0.11037		
"	28-C	61,164	"	16.52	0.00189		40.48		15.48	5.36	46,360	0.0310	626.6	0.11037		
"	28-D	60,881	"	16.15	0.00114		41.24		14.66	4.05	44,720	0.0228	604.6	0.11037		
"	28-E	60,881	"	16.22	0.00182		41.09		15.15	5.20	46,041	0.0295	622.5	0.09715		
"	30-A	119,214	"	14.33	0.00219	8.9	92.75		11.55	4.98	79,249	0.0120	1071.3	1.73622	28	
"	30-B	119,497	"	13.72	0.00281		99.49		11.28	5.58	82,992	0.0125	1122.2	1.73622		

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 39
BED-LOAD EXPERIMENTS OF H. J. CASEY
PRUSSIAN EXPERIMENT INSTITUTE FOR HYDRAULIC ENGINEERING AND SHIPBUILDING

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G(2) grams per second per centimeter	Duration of run minutes	Bed condition
Nominal slope	Run no.						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND h																
1:200	9	6,000	40	3.35	0.00499		44.7		3.16	3.93	11,388	0.0158	141.2	0.00024	15	Smooth bed
"	10	6,900	"	3.60	0.00499		47.8		3.37	4.06	13,002	0.0154	161.2	0.00079	15	" "
"	11	6,710	"	3.53	0.00494		47.4		3.31	4.00	12,649	0.0152	156.8	0.00079	17	" "
"	12	7,620	"	3.85	0.00491		49.3		3.59	4.16	14,285	0.0155	177.1	0.01553	23	" "
"	13	9,170	"	4.26	0.00496		53.6		3.94	4.38	17,027	0.0152	211.1	0.15167	16	" "
"	14	10,600	"	4.65	0.00505		56.8		4.27	4.60	19,621	0.0153	242.7	0.18923	19	" "
"	15	12,500	"	5.16	0.00498		60.4		4.70	4.79	22,954	0.0152	283.9	0.13199	19	Light riffles
"	16	14,700	"	5.81	0.00500		63.1		5.26	5.08	26,806	0.0157	331.6	0.35257	14	Riffles
"	17	18,800	"	6.78	0.00509		69.1		6.05	5.49	33,785	0.0159	417.9	0.59503	1225	"
"	18	11,100	"	4.73	0.00506		58.4		4.33	4.64	20,452	0.0150	253.0	0.12367	11.5	Light riffles
"	19	9,380	"	4.16	0.00502		56.1		3.83	4.34	17,361	0.0143	214.8	0.01969	11.5	Smooth bed
"	20	8,000	"	3.78	0.00509		52.7		3.51	4.19	14,949	0.0145	184.9	0.07839	16	" "
"	21	6,170	"	3.24	0.00498		47.5		3.04	3.85	11,666	0.0145	144.3	0.01517	12.5	" "
"	22	4,750	"	2.72	0.00496		43.5		2.57	3.54	9,038	0.0141	111.8	0.00912	6	" "
1:400	9	9,300	40	5.30	0.00250		43.7		4.81	3.43	17,229	0.0151	210.2	0.00069	16	" "
"	10	11,100	"	5.82	0.00251		47.5		5.11	3.55	19,903	0.0145	242.8	0.00069	32	" "
"	11	12,300	"	6.27	0.00250		48.9		5.58	3.70	22,305	0.0149	273.0	0.00259	15.5	" "
"	12	14,400	"	6.67	0.00250		53.8		5.83	3.78	25,625	0.0140	313.7	0.01458	17	Long waves
"	13	15,300	"	7.37	0.00251		51.8		6.49	4.00	27,479	0.0156	336.3	0.03055	15.5	" "
"	14	16,600	"	7.71	0.00245		53.7		6.72	4.02	29,496	0.0152	361.0	0.04521	15	" "
"	15	17,400	"	7.97	0.00248		54.5		6.94	4.11	30,892	0.0154	378.1	0.04944	14	" "
"	16	18,800	"	8.34	0.00248	No Observations	56.3	No Observations	7.26	4.19	32,378	0.0153	405.7	0.06373	35	" "
"	17	20,000	"	8.72	0.00249		57.2		7.51	4.28	34,274	0.0154	429.4	0.08327	17.5	" "
"	18	21,900	"	9.22	0.00251		59.2		7.88	4.41	37,245	0.0156	466.7	0.11857	15	" "
"	19	23,200	"	9.51	0.00256		60.9		8.09	4.51	39,310	0.0155	492.6	0.13257	22	Waves
"	20	25,000	"	9.81	0.00290		63.5		8.39	4.89	42,529	0.0163	532.9	0.19615	19.5	"
"	21	17,800	"	7.89	0.00240		56.4		6.79	4.00	30,541	0.0144	382.7	0.05498	18.5	"
"	22	17,700	"	7.96	0.00253		55.5		6.91	4.14	30,694	0.0153	383.7	0.05301	16.5	"
"	23	20,200	"	8.86	0.00249		56.8		7.64	4.32	34,725	0.0158	434.1	0.08750	17	"
"	24	23,000	"	9.61	0.00252		59.6		8.21	4.50	39,131	0.0159	489.1	0.14132	14.5	"
"	25	24,400	"	9.84	0.00250		61.9		8.31	4.51	41,126	0.0154	514.1	0.26069	12	"
"	26	32,700	"	12.18	0.00250		67.0		10.04	4.96	53,793	0.0161	672.4	0.18194	17.5	"
"	27	41,300	"	13.79	0.00250		74.7		10.94	5.18	65,348	0.0153	816.8	0.58336	12	"
1:800	9	22,600	40	11.70	0.00125		48.2		9.58	3.43	37,336	0.0153	461.9	0.00091	16	Smooth bed
"	10	26,300	"	12.84	0.00130		51.0		10.40	3.64	42,878	0.0156	530.4	0.00392	13	" "
"	11	29,600	"	13.86	0.00130		53.3		11.05	3.75	47,625	0.0156	589.1	0.00679	14.5	" "
"	12	32,000	"	14.74	0.00123		54.1		11.55	3.73	50,509	0.0154	624.8	0.00698	11.5	" "
"	13	35,000	"	15.66	0.00120		55.8		12.04	3.76	54,465	0.0151	671.6	0.00704	14.5	" "
"	14	38,500	"	16.55	0.00119		58.0		12.47	3.82	58,659	0.0148	723.3	0.00994	16.5	" "
"	15	44,000	"	17.58	0.00120		62.5		12.76	3.88	64,695	0.0141	797.7	0.02060	17	" "
"	16	47,500	"	18.27	0.00123		64.9		13.05	3.97	68,664	0.0139	846.6	0.03518	14.5	" "
"	17	48,900	"	18.76	0.00119		65.0		13.27	3.94	69,971	0.0138	862.7	0.03544	14.5	" "
"	18	52,500	"	19.42	0.00125		67.5		13.62	4.09	74,579	0.0139	919.6	0.06162	14.5	Light waves
"	19	56,000	"	20.65	0.00129		67.6		14.61	4.30	80,296	0.0147	987.6	0.08298	14	" "
"	20	57,800	"	21.90	0.00128		66.0		15.70	4.44	84,255	0.0158	1036.3	0.07905	21.5	" "
"	21	49,200	"	18.70	0.00140		65.7		13.78	4.35	73,616	0.0152	905.5	0.03806	32	" "
"	22	40,500	"	18.15	0.00125		56.7		13.99	4.14	64,509	0.0168	793.5	0.00963	26.5	" "
"	23	29,800	"	14.49	0.00126		51.4		11.63	3.79	48,592	0.0164	597.7	0.00182	22	" "
"	24	21,200	"	11.66	0.00121		45.4		9.70	3.39	35,785	0.0162	440.2	0.00001	19	" "
SAND III A																
1:200	9	1,670	40	1.32	0.00506		31.6		1.28	2.52	3,341	0.0123	40.3	0.00180	33	Light riffles
"	10	2,300	"	1.67	0.00504		34.4		1.61	2.82	4,577	0.0132	55.2	0.00807	61	Long "
"	11	2,830	"	1.92	0.00500	No Observations	36.8	No Observations	1.84	3.00	5,604	0.0134	67.6	0.01838	18	Riffles
"	12	3,840	"	2.35	0.00481		40.9		2.23	3.24	7,557	0.0134	91.2	0.07474	20	"
"	13	6,240	"	3.16	0.00500		49.3		2.95	3.80	12,053	0.0137	145.5	0.28402	20	"
"	14	12,500	"	4.98	0.00497		63.0		4.50	4.69	23,509	0.0142	283.8	0.84952	20	"
"	15	4,180	"	2.44	0.00519		42.9		2.26	3.39	8,047	0.0135	97.1	0.04805	20	"
"	16	3,210	"	2.05	0.00498		39.2		1.95	3.09	6,346	0.0131	76.6	0.03019	23	"
"	17	1,690	"	1.37	0.00502		30.8		1.33	2.56	3,392	0.0129	40.8	0.00912	116	"
"	18	805	"	0.90	0.00509		22.4		0.88	2.10	1,646	0.0136	19.8	0.00129	23	"

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, ond V_m is in feet per secono.

(2) Dry weight.

TABLE 39 (CONTINUED)
BED-LOAD EXPERIMENTS OF H. J. CASEY
PRUSSIAN EXPERIMENT INSTITUTE FOR HYDRAULIC ENGINEERING AND SHIPBUILDING

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
Nominal slope	Run No.						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
SAND III (CONTINUED)																
1:400	7	1,890	40	1.58	0.00255		29.9		1.50	1.94	3,683	0.0103	44.8	0.00182	19	Smooth bed
"	8	2,370	"	1.84	0.00251		32.2		1.73	2.07	4,583	0.0104	55.8	0.00614	17	" "
"	9	2,820	"	2.06	0.00255		34.2		1.93	2.20	5,424	0.0106	66.0	0.00575	88	Riffles
"	10	3,630	"	2.47	0.00255		36.8		2.30	2.40	6,943	0.0111	84.5	0.01371	27	"
"	11	4,220	"	2.87	0.00252		36.7		2.67	2.57	8,069	0.0122	97.9	0.02129	51	"
"	12	5,360	"	3.36	0.00248		39.9		3.09	2.74	10,154	0.0123	123.2	0.04310	27	"
"	13	6,240	"	3.64	0.00248		42.7		3.31	2.84	11,659	0.0121	141.4	0.05797	20	"
"	14	10,300	"	5.11	0.00231		50.4		4.49	3.19	18,698	0.0121	226.2	0.12615	16	"
"	15	12,600	"	6.00	0.00246		52.5		5.26	3.56	22,831	0.0133	276.3	0.21949	12	"
"	16	19,400	"	8.36	0.00236		58.0		7.13	4.06	34,162	0.0144	413.4	0.37189	11	"
"	17	11,200	"	5.50	0.00266		50.9		4.89	3.57	20,570	0.0136	248.9	0.28658	9	"
"	18	6,370	"	3.88	0.00249		41.0		3.55	2.95	12,039	0.0131	145.7	0.01794	33	"
"	19	4,570	"	3.20	0.00248		35.7		2.98	2.69	8,792	0.0134	106.4	0.00411	36	"
"	20	3,360	"	2.70	0.00248	No Observations	31.1	No Observations	2.55	2.49	6,570	0.0139	79.3	0.00088	113	"
"	21	2,160	"	2.08	0.00254		26.0		1.99	2.23	4,293	0.0143	51.8	0.00049	36	"
1:800	11	3,960	40	3.17	0.00120		31.2		2.86	1.84	7,262	0.0104	89.3	0.00104	32	Smooth bed
"	12	4,870	"	3.59	0.00121		33.9		3.20	1.95	8,817	0.0103	108.4	0.00184	14	" "
"	13	6,140	"	4.14	0.00125		37.1		3.64	2.11	10,970	0.0105	134.9	0.00652	17	" "
"	14	7,650	"	4.82	0.00127		39.6		4.18	2.28	13,461	0.0108	165.6	0.01240	16	" "
"	15	9,390	"	5.61	0.00125		41.8		4.79	2.42	16,292	0.0112	200.4	0.01947	17	Riffles
"	16	11,050	"	6.56	0.00129		42.1		5.62	2.67	19,219	0.0125	236.4	0.02654	43	"
"	17	14,000	"	7.95	0.00121		44.0		6.67	2.81	23,860	0.0184	293.5	0.04098	25	"
"	18	16,700	"	8.86	0.00131		47.0		7.38	3.08	28,200	0.0136	346.9	0.04550	24	"
"	19	19,200	"	9.85	0.00125		48.7		8.04	3.14	31,845	0.0135	391.7	0.07511	19	"
"	20	21,000	"	10.84	0.00123		48.5		8.85	3.27	34,877	0.0144	429.0	0.06803	14	"
"	21	12,200	"	7.36	0.00125		41.4		6.30	2.78	21,218	0.0135	261.0	0.01407	17	"
"	22	12,050	"	7.34	0.00126		41.1		6.31	2.79	21,068	0.0137	259.1	0.01407	77	"
"	23	25,900	"	12.10	0.00130		53.5		9.63	3.50	41,895	0.0142	515.3	0.12652	17	"
"	24	29,900	"	13.00	0.00185		57.5		10.73	4.41	50,137	0.0169	616.7	0.23480	14	"
"	25	15,900	"	9.12	0.00120		43.6		7.67	3.00	27,188	0.0143	334.4	0.01808	37	Light riffles
"	26	11,300	"	7.05	0.00125		40.0		6.09	2.73	19,808	0.0137	243.6	0.00933	23	" "
"	27	9,050	"	6.15	0.00120		36.8		5.39	2.52	16,123	0.0134	198.3	0.00438	85	" "
"	28	5,760	"	4.72	0.00119		30.5		4.28	2.23	10,603	0.0138	130.4	0.00144	20	" "

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 40
BED-LOAD EXPERIMENTS OF HO PANG-YUNG
PRUSSIAN EXPERIMENT INSTITUTE FOR HYDRAULIC ENGINEERING AND SHIPBUILDING

Author's references: Table (1)	Author's references: Experiment no. (2)	Discharge, Q cubic centimeters per second (3)	Width of flume, B centimeters (4)	Mean water depth, D centimeters (5)	Water surface slope, S (6)	Water temperature degrees centigrade (7)	Velocity centimeters per second: Mean V_m (8)	Velocity centimeters per second: Bottom V_b (9)	Hydraulic radius of bed, r_b centimeters (10)	Friction velocity, V^* centimeters per second (11)	Reynolds Number, R (12)	Manning's n of bed, n_b (1) (13)	Unit discharge, q_b cubic centimeters per second per centimeter (14)	Rate of bed movement, G (2) grams per second per centimeter (15)	Duration of run minutes (16)	Bed condition (17)
MIXTURE I																
1	7	50,400	40	21.75	0.00106	15.6	57.85	No Observations	15.91	4.07	81,451	0.0165	920.4	0.00015	50	No Observations
"	8	68,700	"	26.25	0.00105	15.7	65.20		17.77	4.28	102,719	0.0157	1158.7	0.00088	50	
"	4	30,960	"	14.16	0.00126	15.3	54.60		11.10	3.70	53,261	0.0150	606.1	0.00064	40	
"	5	43,900	"	18.27	0.00127	15.3	60.00		13.76	4.14	72,533	0.0158	825.4	0.00139	50	
"	6	53,000	"	21.02	0.00125	15.4	63.00		15.37	4.34	85,216	0.0161	968.1	0.00233	50	
"	7	67,800	"	24.62	0.00128	15.5	86.85		14.08	4.20	108,048	0.0112	1223.1	0.00554	50	
"	2	19,820	"	10.39	0.00171	15.3	47.65		8.94	3.87	37,412	0.0174	425.8	0.00055	40	
"	3	33,440	"	14.20	0.00170	15.2	58.90		11.46	4.37	59,101	0.0165	674.9	0.00051	50	
"	4	52,200	"	19.13	0.00170	15.2	68.24		14.53	4.92	86,818	0.0167	991.5	0.00671	50	
"	5	64,500	"	22.25	0.00165	15.3	72.50		16.24	5.13	103,481	0.0167	1177.6	0.01604	50	
"	6	68,600	"	22.47	0.00164	14.9	72.20		16.41	5.14	103,051	0.0168	1185.1	0.01677	50	
"	2	19,200	"	7.97	0.00335	15.0	60.22		7.01	4.80	36,793	0.0163	422.4	0.01313	50	
"	3	34,750	"	11.68	0.00336	15.0	74.10		9.77	5.67	63,062	0.0166	724.0	0.06563	50	
"	4	48,700	"	14.34	0.00336	15.1	84.90		11.47	6.15	85,086	0.0161	973.4	0.34272	50	
"	5	69,450	"	17.86	0.00340	15.1	90.86		13.93	6.82	110,644	0.0172	1265.8	0.86775	50	
MIXTURE II																
1	7	55,950	40	22.17	0.00127	15.8	63.10	No Observations	16.26	4.50	91,212	0.0168	1026.1	0.00015	50	No Observations
"	8	65,250	"	24.62	0.00128	15.8	66.31		17.59	4.70	103,685	0.0169	1166.5	0.00036	50	
"	4	37,750	"	15.52	0.00167	15.7	60.76		12.34	4.50	66,459	0.0167	749.7	0.00029	50	
"	5	49,100	"	18.44	0.00169	15.7	66.60		14.13	4.84	83,451	0.0168	941.3	0.00095	50	
"	6	56,550	"	20.30	0.00167	15.6	69.70		15.17	4.99	93,595	0.0167	1057.6	0.00160	50	
"	7	64,100	"	21.89	0.00167	15.6	73.13		15.97	5.11	103,346	0.0164	1167.8	0.00335	50	
"	2	16,150	"	7.30	0.00335	15.4	55.32		6.53	4.63	31,819	0.0170	361.5	0.00146	50	
"	3	29,250	"	10.55	0.00334	15.5	69.40		8.98	5.42	55,042	0.0167	623.1	0.01094	50	
"	4	42,650	"	13.54	0.00335	15.5	78.75		11.11	6.04	77,289	0.0170	874.9	0.08167	50	
"	5	54,350	"	16.25	0.00334	15.6	83.50		13.06	6.54	96,483	0.0178	1090.3	0.11667	50	
"	6	63,050	"	17.70	0.00336	15.7	89.20		13.88	6.76	109,737	0.0175	1237.8	0.19251	50	
MIXTURE III																
1	7	64,450	40	22.30	0.00169	16.0	72.10	No Observations	16.44	5.22	105,990	0.0171	1185.0	0.00029	50	No Observations
"	3	30,250	"	10.61	0.00334	15.5	71.40		8.96	5.42	56,514	0.0162	639.7	0.00095	50	
"	4	44,400	"	13.82	0.00335	15.5	80.80		11.24	6.08	80,250	0.0167	908.4	0.00729	50	
"	5	53,900	"	16.11	0.00333	14.9	83.80		12.92	6.50	94,147	0.0176	1082.7	0.01021	50	
"	6	65,050	"	17.97	0.00335	15.0	90.50		13.99	6.78	110,287	0.0173	1266.1	0.03281	50	
"	2	33,050	"	10.22	0.00502	14.7	80.90		8.81	6.59	61,708	0.0174	712.7	0.00467	50	
"	3	50,150	"	13.52	0.00504	14.6	92.70		11.24	7.45	89,994	0.0179	1042.1	0.12178	50	
"	4	64,050	"	15.77	0.00502	14.7	101.30		12.72	7.91	111,553	0.0177	1288.4	0.13271	50	
MIXTURE IV																
1	3	14,650	40	9.63	0.00100	12.8	38.05	No Observations	8.20	2.84	25,643	0.0157	311.8	0.00109	30	No Observations
"	4	25,500	"	13.28	0.00102	13.5	48.00		10.51	3.24	42,326	0.0148	504.5	0.00997	30	
"	5	36,950	"	17.15	0.00101	14.2	53.80		12.88	3.57	59,125	0.0150	692.9	0.01458	30	
"	6	49,500	"	20.62	0.00103	14.4	60.10		14.64	3.85	75,460	0.0148	879.9	0.07778	30	
"	7	62,850	"	24.93	0.00104	14.5	63.00		17.21	4.19	93,329	0.0159	1084.5	0.12396	30	
"	3	23,670	"	12.03	0.00125	14.7	49.20		9.79	3.46	41,711	0.0153	481.8	0.01045	30	
"	4	39,250	"	16.59	0.00126	14.8	59.20		12.54	3.94	64,452	0.0150	742.5	0.07292	30	
"	5	48,950	"	19.79	0.00126	15.0	61.80		14.65	4.25	78,838	0.0160	905.1	0.13612	30	
"	6	63,050	"	22.59	0.00125	15.2	69.70		15.52	4.36	94,222	0.0147	1081.7	0.21147	30	
"	2	13,650	"	8.23	0.00167	15.1	41.50		7.28	3.45	26,359	0.0171	302.1	0.00182	30	
"	3	25,540	"	11.88	0.00166	15.1	53.60		9.85	4.01	46,088	0.0162	528.2	0.07316	30	
"	4	37,800	"	14.83	0.00166	15.1	63.80		11.55	4.34	64,273	0.0152	736.6	0.21876	30	
"	5	52,200	"	19.68	0.00168	15.2	66.30		15.10	4.99	87,688	0.0180	1001.4	0.25522	30	
"	6	63,150	"	22.48	0.00167	15.3	70.30		16.75	5.24	103,461	0.0177	1177.4	0.34515	30	
MIXTURE V																
1	3	30,250	40	10.94	0.00333	10.8	69.10	No Observations	9.32	5.52	50,130	0.0172	643.7	0.00109	50	No Observations
"	4	44,800	"	14.47	0.00335	11.0	77.50		11.93	6.26	72,352	0.0181	924.7	0.00802	50	
"	5	53,700	"	16.58	0.00334	11.5	81.00		13.46	6.64	86,548	0.0187	1090.5	0.01050	50	
"	6	65,050	"	17.39	0.00333	11.7	93.50		13.33	6.60	99,542	0.0161	1246.3	0.03573	50	
"	2	33,050	"	10.04	0.00500	12.2	82.20		8.62	6.50	57,321	0.0168	708.5	0.00656	50	
"	3	50,150	"	13.50	0.00500	12.6	92.90		11.19	7.41	84,946	0.0177	1039.7	0.16042	50	
"	4	64,050	"	15.70	0.00501	12.9	102.00		12.62	7.88	106,146	0.0175	1287.5	0.30189	50	

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.

TABLE 40 (CONTINUED)

BED-LOAD EXPERIMENTS OF HO PANG-YUNG

PRUSSIAN EXPERIMENT INSTITUTE FOR HYDRAULIC ENGINEERING AND SHIPBUILDING

Author's references		Discharge, Q cubic centimeters per second	Width of flume, B centimeters	Mean water depth, D centimeters	Water surface slope, S	Water temperature degrees centigrade	Velocity centimeters per second		Hydraulic radius of bed, r_b centimeters	Friction velocity, V^* centimeters per second	Reynolds Number, R	Manning's n of bed, n_b (1)	Unit discharge, q_b cubic centimeters per second per centimeter	Rate of bed movement, G (2) grams per second per centimeter	Duration of run minutes	Bed condition
Table	Experiment no.						Mean V_m	Bottom V_b								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
MIXTURE VI																
2	3	6,000	40	5.05	0.00100	13.5	29.70	No Observations	4.36	2.07	10,864	0.0132	129.5	0.00122	30	No Observations
"	4	12,820	"	8.45	0.00100	13.5	37.95		6.82	2.59	21,711	0.0139	258.8	0.03524	"	
"	5	23,700	"	12.46	0.00099	13.6	47.50		9.10	2.98	36,450	0.0134	432.3	0.08143	"	
"	6	41,660	"	18.95	0.00100	13.6	55.01		12.67	3.53	58,769	0.0145	697.0	0.21147	"	
"	2	6,000	"	5.10	0.00100	28.5	29.40		4.46	2.09	15,533	0.0136	131.1	0.00365	"	
"	3	12,820	"	8.57	0.00101	29.3	37.40		7.07	2.65	31,855	0.0145	264.4	0.05347	"	
"	4	23,700	"	12.67	0.00100	30.7	46.75		9.57	3.07	55,440	0.0142	447.4	0.14584	"	
"	5	41,660	"	20.27	0.00100	31.6	51.40		14.60	3.79	94,628	0.0170	750.4	0.32814	"	
"	1	3,400	"	3.63	0.00100	41.0	23.43		3.32	1.81	11,733	0.0140	77.8	0.00340	"	
"	2	6,000	"	5.27	0.00100	42.7	28.50		4.67	2.14	20,732	0.0144	133.1	0.01945	"	
"	3	12,820	"	8.65	0.00101	43.6	37.04		7.23	2.68	42,373	0.0150	267.8	0.09480	"	
"	4	23,700	"	12.73	0.00102	44.4	46.55		9.81	3.14	73,189	0.0146	456.7	0.20661	"	
"	5	41,660	"	21.77	0.00100	44.0	47.86		16.49	4.02	125,669	0.0198	789.2	0.40592	"	
2	1	6,000	"	5.00	0.00100	2.0	30.00		4.26	2.05	7,612	0.0129	127.8	0.00109	"	
"	2	12,820	"	8.40	0.00100	1.6	38.65		6.62	2.55	15,035	0.0134	255.9	0.03038	"	
"	3	23,700	"	12.11	0.00099	1.5	48.90		8.48	2.88	24,280	0.0124	414.7	0.06806	"	
"	4	41,660	"	18.36	0.00100	2.2	56.70		11.59	3.38	39,400	0.0130	657.2	0.15799	"	
"	2	5,900	"	4.85	0.00100	5.5	30.44		4.14	2.00	8,400	0.0125	126.0	0.00122	"	
"	3	12,680	"	8.22	0.00100	5.8	38.55		6.52	2.53	16,888	0.0134	251.3	0.03281	"	
"	4	23,740	"	12.35	0.00099	6.4	48.10		8.80	2.93	28,973	0.0130	423.3	0.07292	"	
"	5	41,660	"	18.41	0.00100	7.0	56.60		11.79	3.41	46,502	0.0135	667.3	0.17987	"	
"	2	6,000	"	5.10	0.00100	11.7	29.40		4.41	2.08	10,351	0.0135	129.7	0.00122	"	
"	3	12,820	"	8.60	0.00100	11.8	37.25		6.97	2.62	20,768	0.0144	259.6	0.03403	"	
"	4	23,700	"	12.30	0.00101	12.0	48.17		8.93	2.98	34,582	0.0132	430.2	0.08264	"	
"	5	41,660	"	18.60	0.00099	12.3	56.00		12.15	3.44	55,227	0.0138	680.4	0.20661	"	

(1) $n_b = \frac{1.486}{V_m} r_b^{2/3} S^{1/2}$ where r_b is in feet, and V_m is in feet per second.

(2) Dry weight.